Early colonization of Beringia and Northern North America: Chronology, routes, and adaptive strategies

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ARTICLE INFO

ABSTRACT

Recent archaeological and paleoecological work along both interior and coastal routes for early colonization of the New World has suggested that the interior route was impossible, leaving the coastal route as the only colonization route taken by Clovis ancestors. We review the geological, paleoecological, and archaeological record for Eastern Beringia and adjacent areas. Spatio-temporal patterning of known sites and evaluation of early interior and coastal route radiocarbon, luminescence, and cosmogenic dating, along with new analyses of obsidian distribution and adaptive strategies of early Beringians, indicate this assessment is premature and the interior route remains a viable hypothesis, available by at least 13,560 and possibly 14,900 years ago.

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1. Introduction

The early colonization(s) of the Americas represent important avenues to explore human ecology, human-climate interactions, humans' role in extinctions, and adaptive capacities. Given current disagreements in archaeology, genetics, and interpretations of paleoenvironmental patterning, clarifying the nature, number, timing, and environmental contexts of these colonization events is critical. There are several points of widespread consensus that help guide this paper. The first Americans and/or the ancestors of the first widespread cultural traditions south of the Laurentide and Cordilleran Ice Sheets originated in Northeast Asia and expanded into Beringia before migrating farther south into North and South America. These populations were genetically related most closely to modern East Asians, but with significant admixture from a now-vanished *Ancient North Eurasian* population of interior Siberia (Raghavan et al., 2015). However, recent papers have asserted certainty for the coastal route of colonization and/or the impossibility of the interior route (Erlandson, 2013, Erlandson et al., 2015; Madsen, 2015), at least prior to 13,000 cal yr BP (Heintzman

et al., 2016) or 12,600 cal yr BP[1] (Pedersen et al., 2016). Other studies of human genetics have made similar assertions, though providing no geological or archaeological evaluation of the data (Llamas et al., 2016; Skoglund and Reich, 2016). We contend these assertions of certainty are premature and are inconsistent with a comprehensive understanding of the extant data.

In this paper, we evaluate the Beringian archaeological record, including recent data generated by ongoing research programs directed by Potter, Holmes, and Reuther, in terms of chronological and spatial patterning of the earliest occupations and broad economic, technological, settlement systems and habitat use. We then provide a systematic evaluation of extant data from both hypothetical routes for entry into central North America, the Ice Free Corridor (interior route) and the Northwest Pacific Coast (NPC, coastal route). We test expectations for both routes for early (pre-Paleo-Eskimo) migrations and regional chronologies within Eastern Beringia and adjacent NPC areas. A clearer understanding of the ecological adaptations of early Beringians can provide us with avenues to link broad environmental change with human responses,

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[1] Due to multiple age techniques evaluated in this paper, we use the following conventions: ^{14}C yr BP for uncalibrated radiocarbon dates, cal yr BP for calibrated dates, and kya for OSL and cosmogenic dates and for genetic age estimates. All of these are roughly comparable except for ^{14}C yr BP.

including expansion, contraction, and land use shifts. We review the spatiotemporal distribution of archaeological sites in Beringia and adjacent alternative routes. We evaluate obsidian distributions in both coastal and interior regions with respect to expectations for coastal or interior colonization models. We also identify where we currently lack knowledge and propose that future research focus on these areas of ambiguity.

1.1. Clovis or Pre-Clovis ancestors?

For this review, we must be clear about the colonization event(s) under consideration. Many previous colonization studies assume that Clovis complex-using populations were responsible for the initial peopling of the New World, the "Clovis First Model" (Meltzer, 2009:4—5). On one hand, there is support for this model from genetic evidence, which suggests the initial peopling of the New World by a single relatively small population (Raghavan et al., 2015) and a rapid colonization from north to south (Barton et al., 2004; Hamilton and Buchanan, 2007). Similarly, decreasing heterozygosity from north to south is consistent with a north-south movement (Wang et al., 2007), though it could be due to differential gene flow with Asians (Tamm et al., 2007). On the other hand, there are a growing number of sites proposed to pre-date the Clovis culture (Adovasio et al., 2013; Collins et al., 2013; Erlandson, 2013), although they are not without their critiques (Dincauze, 1984; Fiedel, 2013; Haynes and Huckell, 2016; Meltzer, 2009: 95—124; Morrow et al., 2012).

Consequently, there has been a renewed interest in examining Clovis lithic technology across North America to re-visit some of the central tenets of the "Clovis First Model." For example, one of the key aspects of the Clovis First Model is the similarity in lithic technology across North America, seen particularly in the production of prismatic blades and fluted bifaces (Bradley et al., 2010; Collins, 1999; Eren and Buchanan, 2016). However, while fluted bifaces are remarkably consistent across areas of North America, in some cases analysts have detected subtle variations in their production and final shape that have been interpreted as "cultural drift" derived from a founding population (Eren et al., 2015; Smith et al., 2014). In the Great Lakes and northeastern United States, people using Clovis technology and later post-Clovis groups were clearly the first people to move into areas that had been recently deglaciated (Eren, 2013; Lothrop et al., 2016).

However, what is less clear is the origin of Clovis technology and its relationship, if any, with purported pre-Clovis sites. Pre-Clovis sites vary in their integrity and chronological controls, but there is as yet little consensus as to their technological, typological, or derived historical connections with later widespread cultural traditions (Collins et al., 2013; Fiedel, 2013; Waters et al., 2013; but see also Adovasio et al., 2013). These sites may represent earlier migrations that left little or no genetic contribution to recent/modern Native Americans, or in other words "failed migrations" (Meltzer, 1989:472).

For our purposes, we do not assume that Clovis represents the earliest colonization. Instead, we contend that the Clovis complex and related Paleoindian materials are the first *widespread* cultural manifestation south of the Ice Sheets. Based on a sample of 13 sites, Waters and Stafford (2007, 2014:544) contend that the Clovis complex spans "11,080 ± 40 ^{14}C yr BP (Lange-Ferguson, SD) to 10,705 ± 35 ^{14}C yr BP (Anzick, Montana)." They question the accuracy of the radiocarbon dates and/or their association with artifacts at four sites (Aubrey, Texas; Casper, Wyoming; East Wenatchee, Washington; and Sheaman, Wyoming). Haynes et al. (2007), however, argue that the dates from Aubrey should not be summarily dismissed. Since then an additional site, El Fin del Mundo, a proboscidean kill site in Sonora with associated Clovis

points, has been argued to pre-date this age range (Sanchez et al., 2014). Moreover, given the vagaries in the radiocarbon calibration curve associated with the onset of the Younger Dryas (Fiedel, 2014), and the statistical uncertainty associated with using a small number of sites to extrapolate an age range for Clovis (Prasciunas et al., 2015), there is basically a short chronology (12,940—12,680 cal yr BP [11,050 to 10,800 ^{14}C yr BP]) and a long chronology (~13,400—12,680 cal yr BP [11,600—10,800 ^{14}C yr BP]) for the duration of the Clovis cultural complex (Miller et al., 2013).

Technological analyses indicate technological links between the Siberian Upper Paleolithic and Clovis complex (Straus et al., 2005), and we concur. There is a similarly robust record of human occupation in Eastern Beringia dating from 14,000 cal yr BP (Potter et al., 2013), with clear technological linkages to the Siberian Late Upper Paleolithic (e.g., Yi et al., 1985; Holmes, 2011). Similarly, we concur with studies that argue that Fishtail points from South America post-date the Clovis complex (Waters et al., 2015) and are likely derived from it as well (Morrow and Morrow, 1999; Pearson, 2004:91). Our goal in this article is to evaluate the colonization of Eastern Beringia and the route(s) used by Clovis and Fishtail complex progenitors.

1.2. Implications of ancient/modern genetic analyses on New World colonization

Recent genetic research focused on both mtDNA (Llamas et al., 2016; this volume; Achilli et al., 2013; Perego et al., 2009) and nuclear genomic data (Raghavan et al., 2015; Skoglund et al., 2015) has transformed our understanding of population divergence, admixture, and migration into the Americas. Currently, data suggest that all modern Native Americans (excluding Eskimo populations) draw the vast majority of their ancestry from a single genetically diverse founding population (Hey, 2005; Raghavan et al., 2015; Reich et al., 2012; Zegura et al., 2004). Coalescence estimates for modern Native American haplogroups range from 25 to 15 kya, assuming different mutation rates (Llamas et al., 2016; Perego et al., 2010).

As genetic studies are reliant on modern populations and a few ancient samples, they can directly provide only limited information on the geographic locations of these ancient populations, how they changed in time, and routes of migration. The distributions among modern peoples of three mtDNA haplogroup, X2a and C4c centered at the southern end of the former IFC and D4h3a concentrated along the Pacific coast, have been hypothesized to reflect separate migration pulses (Perego et al., 2009; Kashani et al., 2012). As coalescence ages for these three haplogroups are similar, they may be evidence of two coterminous dispersal routes from Beringia to central North America. We note, however, that while D4h3a has been argued to reflect a remnant of an early coastal migration (Perego et al., 2009), the oldest occurrence of D4h3a is found within a Clovis individual (Anzick), located on the eastern side of the Rocky Mountains (Rasmussen et al., 2014). Based on the ages of Anzick and the younger *Shuká Kaa* individual, and the modern coastal distribution, these data are more consistent with a later (post-12,600 cal yr BP) expansion from the North American interior to the Pacific coast.

mtDNA analyses indicate divergence of Native American ancestors from East Asian ancestors and a long period of genetic differentiation (~40—16 kya) prior to rapid colonization of/expansion in the New World around 16—12 kya (termed the 'Beringian incubation or standstill model') (Tamm et al., 2007; Mulligan et al., 2008; Faught, this volume). Later studies have narrowed this period of isolation to between 24.9 and 18.4 kya and 16 kya (Llamas et al., 2016 and this volume). The location of this isolation is unknown, but as (1) there is no evidence for human occupation in Chukotka,

Kamchatka, or Eastern Beringia prior to ~14,000 cal yr BP and (2) there is substantial evidence for widespread human occupation in Northeast Asia throughout the period after 40,000 cal yr BP, particularly in Southern Siberia (Goebel, 2002), we suspect that this isolation occurred farther west in Asia (for similar arguments, see Madsen, 2015; Buvit and Terry, 2016). Hoffecker et al. (2016) speculate this isolation may have occurred in the currently inundated part of Central Beringia.

Nuclear genomic analyses indicate a single ancestral Native American population, though with a deep divergence that predates Anzick, separating branches termed Northern Native Americans (Algonkians and the majority ancestry of Athabaskan groups) and Southern Native Americans (all other peoples in North, Central and South America) (Rasmussen et al., 2014). Reich et al. (2012) found that Native Americans descended from a single source population, while Na-Dene (e.g., Chipewyan) had evidence for limited admixture (~10%) from an Asian source, different from that in Eskimo populations. Genomic studies also indicated that Native American ancestors entered no earlier than 23 kya after no more than an 8000 year period of isolation from East Asian populations (Raghavan et al., 2015; Llamas et al., 2016). However, some Amazonian Native Americans have been found to carry minor additional ancestry from a source most closely related to modern day Australasians (Reich et al., 2012; Raghavan et al., 2015; Skoglund et al., 2015). The spatial distribution and intensity of this ancestry component suggest two alternative hypotheses: (1) a recent migration from an Australasian-related source that only reached certain Amazonian groups, or (2) that the Native American ancestral population was structured and carried differential relatedness to separate Asian sources (Skoglund and Reich, 2016); these Amazonian groups, in turn, derive part of their ancestry from a distinct component of such ancestral population. At present, the timing and full nature of this Australasian signal is unknown (see Fiedel, this volume).

In sum, genetic studies are consistent with a scenario of an ancient separation (>20 kya) between ancestral Native Americans and East Asians, a population bottleneck between ~18 and 15 kya (Skoglund and Reich, 2016) which took place either in Beringia or northeast Asia, followed by a rapid expansion consistent with a relatively late migration to/within the New World. Clovis (Anzick) has been linked to the southerly of the two basal branches (Rasmussen et al., 2014), Southern Native Americans. The other basal branch, Northern Native Americans, appears restricted to populations in Northern North America. Most genetic data suggest a single population pulse (Raghavan et al., 2015), lending support for the hypothesis that the earliest widespread cultural manifestation south of the ice sheets, Clovis and related complexes, represents the material culture used by this group after the time they migrated south of the ice sheets.

2. Archaeological record

2.1. Spatio-temporal site patterning

Broad patterns of human occupation and expansion can be inferred from 101 known sites in Eastern Beringia and the two proposed entry routes, which are securely dated to over ~10,000 cal yr BP. This analysis considers the sites compiled by Potter et al. (2013: Tables 5.1 and 5.8), grouped by region: Eastern Beringia (Yukon, Kuskokwim, Susitna, Copper, and adjacent watersheds, n = 70), Pacific coastal corridor (Aleutian Islands, Alaska Peninsula, Kodiak Archipelago, and the Northwest Coast, n = 16), and the interior corridor (Mackenzie and Nelson watersheds and adjacent areas, n = 19). Additional sites include Spein Mountain (Bever, 2001) in Beringia, Niska (Meyer and Liboiron, 1990), Lindoe (Bryan, 2000)

along the interior route and Manis (Grayson and Meltzer, 2002; Gustafson et al., 1979; Haynes and Huckell, 2016; Waters et al., 2011), Ayer Pond (Kenady et al., 2011; Wilson et al., 2009), Irish Creek, Rice Ridge, and Trout Creek (Carlson and Baichtal, 2015) along the coastal route. Ages reported by the original investigators are calibrated with Intcal13 (Reimer et al., 2013) and the median calibrated ages are grouped by 1000-year intervals (Fig. 1).

For the >15,000 cal yr BP period, no sites are known in the region (Fig. 1A). For the 15,000–14,000 cal yr BP period (Fig. 1B), only two sites are known in the broader region, both in the Yukon Watershed (Swan Point cultural zone (CZ) 4b and Little John subpaleosol component). No dated sites are known for either interior or coastal routes. For the period 14,000–13,000 cal yr BP (Fig. 1C), Clovis and Fishtail complex sites are widespread in central North America and South America during the end of this millennium. In Beringia and adjacent areas, 19 sites are known for this period, 13 (68%) in the Yukon Watershed, one in the Arctic Ocean Seaboard (Tuluaq), one at the southern end of the interior route (Wally's Beach), and two (possibly three) at the southern end of the coastal route. Two of the near-coastal sites pre-date Clovis occupations (Manis and Ayer Pond, Kenady et al., 2011, Waters et al., 2011; Wilson et al., 2009), but the association of the dated materials and humans may be equivocal (Grayson and Meltzer, 2002, 2015; Haynes, 2015; Haynes and Huckell, 2016). For the third, Kildidt Narrows (Hunter Island), four widely disparate dates are associated with a single stratigraphic layer (between 11,720 and 9480 cal yr BP (Cannon, 2000; McLaren et al., 2015). It is also unclear if the charcoal was derived from human agency or natural fires (see below). For this entire region, there are thus 21 components older than ~13,000 cal yr BP, all but five in deep interior Eastern Beringia, with one along the interior route and two (or three) along the coastal route (see discussion below). While fluted points in the interior corridor area remain undated, their geographical distribution (Fig. 1C–D) clearly conforms to the 13,300 rather than the 12,500 cal yr BP glacial margins (Ives et al., 2013).

For the period 13,000–12,000 cal yr BP (Fig. 1D), 20 sites are known, including 7 sites in the Yukon Watershed, 5 along the interior route and 2 (possibly 7) along the coastal route which represent the first unequivocal occupations, approximately 1700 years after the initial occupations in interior Eastern Beringia. Three coastal sites with more secure dating and association are K1 Cave and Devil's Point, and a single dated worked bone from Shuká Kaa (formerly known as On Your Knees Cave), while three others, Kildidt Narrows, Cardinalis Creek, and Gaadu Din 1, have multiple non-overlapping younger associated dates (see references below).

For the period 12,000–11,000 cal yr BP (Fig. 1E), there are 28 sites known in the broader region, including 14 sites in the Yukon Watershed and the earliest sites in South Alaska (limited to the Kuskokwim and Susitna drainages) (n = 3) and re-occupation of the Arctic Ocean Seaboard (n = 6). There are 5 sites along the interior route and 3 possible sites along the coastal route during this period. These three coastal sites (Kildidt Narrows, Cardinalis Creek, and Gaadu Din 1) also have younger and/or older associated dates.

For the period 11,000–10,000 cal yr BP (Fig. 1F), there are 29 sites known in the broader region, 15 in Beringia, 5 along the interior route and 9 along the coastal route, with possibly 4 other sites with ages spanning multiple 1000 calendar-year periods (Gaadu Din 2, Kildidt Narrows, Cardinalis Creek, Richardson Island).

There are no known sites during this entire period (15,000–10,000 cal yr BP) in broad stretches of southern coastal or near-coastal Eastern Beringia: Aleutian Islands, Alaska Peninsula, Kenai Peninsula, or the Gulf of Alaska to much of the Alexander Archipelago until later in the early and middle Holocene. For this southern coastal region, the earliest known occupations vary from 7000 to 5000 years after the earliest interior occupations (and 4000
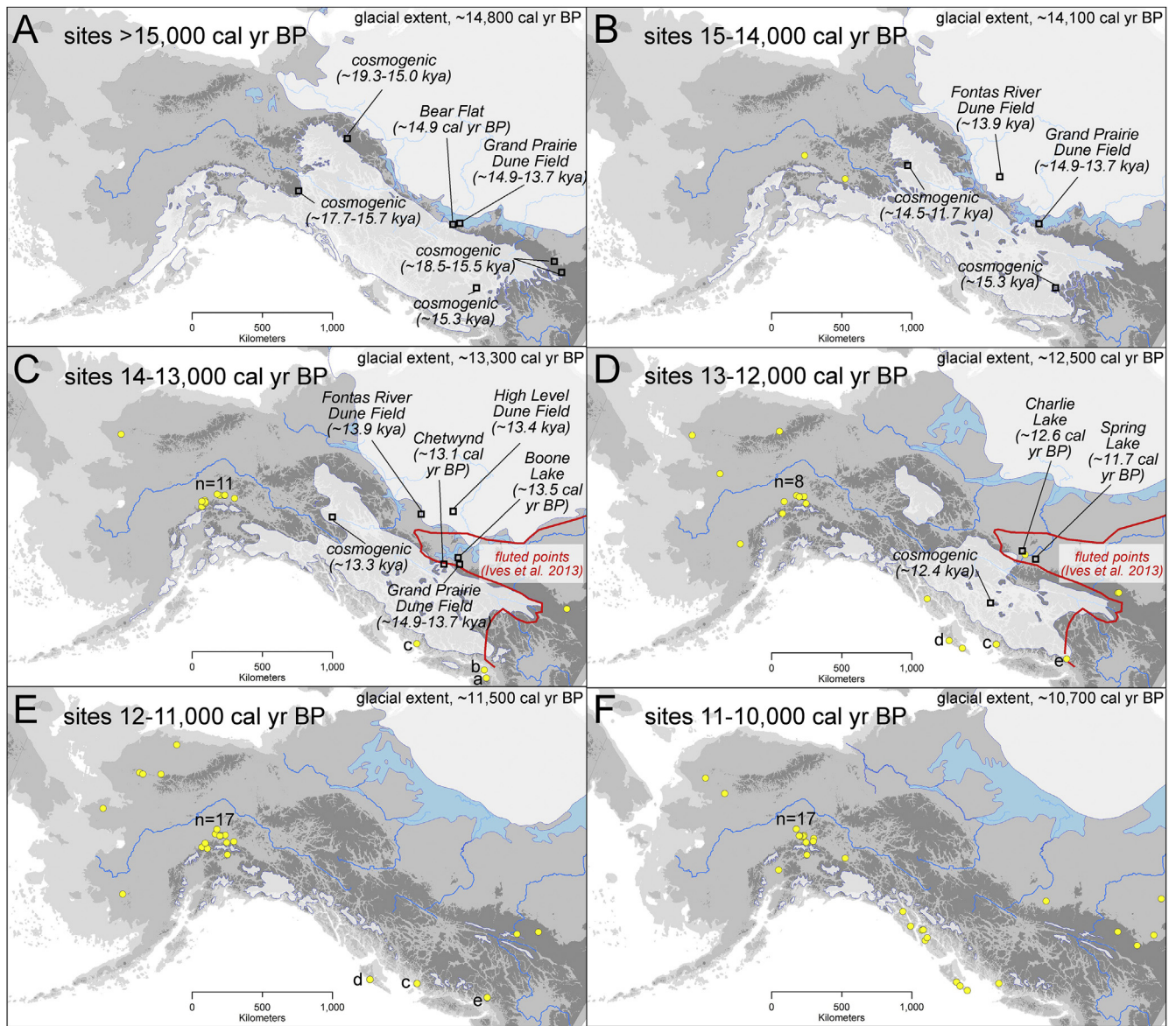
Fig. 1. Distribution of known sites in 1000 cal yr BP intervals with sites (circles) and specific geological or biological sample locations mentioned in the text (squares). Sites discussed in text: a. Manis, b. Ayer Pond, c. Kildidt Narrows, d. Gaadu Din 1, e. Cardinalis, the last three with multiple non-overlapping dates. Cosmogenic data are listed in Table 2. Glacial ice extent from Dyke et al. (2003).

years after widespread Clovis occupations in North America), a pattern that is not expected if there was continuous occupation by descendants of earlier coastal populations. The oldest known Aleutian occupations date to 9000-7000 yr cal BP (Davis et al., 2016), and later expansion westward occurred much later (after ~5500 cal yr BP) (Fitzhugh, 2016). The earliest Kodiak Archipelago occupations date after ~7500 cal yr BP (Steffian et al., 2002), 6500 years after the initial interior Eastern Beringian occupations.

These patterns suggest the initial colonization of Beringia was through interior east-west trending river systems between 14,000–13,000 cal yr BP. The earliest site on the interior route pre-dates or is coeval with earliest Clovis (Wally's Beach) while the earliest unequivocal sites (with associated artifacts) along the coastal route long post-date both interior Eastern Beringian and Clovis occupations. Within Eastern Beringia, at ~12,500–11,000 cal yr BP, there is clear expansion of populations using Denali tradition technologies from the Yukon watershed to adjacent regions, including northern (Brooks Range), southwestern

(Kuskokwim watershed), and southern areas (Susitna watershed, Talkeetna Mountains) (Wygal and Goebel, 2012). This expansion may be due to local effects of the Younger Dryas on resource abundance and diversity (Potter et al., 2013). Only later is there evidence of expansions of Denali-related materials to coastal areas farther south (with sites assigned to the Anangula tradition and Ocean Bay complex) (Ackerman, 2007). While there are only a few securely dated early sites known along the coastal route, there are many sites with microblade-bearing occupations after ~10,700 cal yr BP (Carlson and Baichtal, 2015).

2.2. Eastern Beringian archaeological site samples

The problem of identifying the earliest human presence in Beringia essentially involves archaeological visibility and sampling. While Central Beringia is flooded and Western Beringia has received limited archaeological survey, substantial parts of unglaciated Eastern Beringia are exposed and accessible. Over the past 20

years, we have directed several large-scale survey efforts linked with predictive modeling (Gelvin-Reymiller and Potter, 2009; Potter, 2006; Potter et al., 2002, 2007; Reuther et al., 2013). The data we generated from these surveys and associated excavations are significant. Since 2001, we have discovered ~400 new prehistoric sites in many areas of Eastern Beringia, including 15 Pleistocene-age components (Potter, 2008; Potter et al., 2013). These surveys also act as transects through many different physiographic regions. Some broad patterns of early human land use are emerging. The earliest occupations occur in interior river valleys and highlands (e.g., Yukon-Tanana Uplands) starting at 14,200 cal yr BP. These areas show substantial use between 14,000 and 6000 cal yr BP, while later land use changes dramatically, with increased use of upland areas associated with a shift from bison and wapiti to caribou-dominated faunal assemblages. In contrast, the lowland riverine settings offered more suitable habitats. On the basis of detailed faunal analyses and modern environmental studies (Potter, 2007, 2008; Yesner, 1998, 2001), these areas along major rivers contained many more aggregate resources facilitating multi-seasonal human occupation.

About 1000 years after this earliest occupation in interior highlands and lowlands, the first occupations of a variety of Eastern Beringian physiographic regions occur (~13,000—12,000 cal yr BP): Arctic Coastal Plain, Arctic Foothills, Brooks Range, and Alaska Range. Note that more southerly coastal areas remain uninhabited until much later: Copper River watershed, Aleutian Islands and Alaska Peninsula, Kodiak Archipelago, and the southern Alaska coast along the Gulf of Alaska (see below). Geological data indicate glacial Lake Ahtna was dammed between 26,000—15,500 cal yr BP (Wiedmer et al., 2010). Early coastal populations could have expanded northward along the salmon-rich Copper River, yet there is no evidence for occupation until interior Denali groups expanded south over the Alaska Range passes at ~12,200 cal yr BP (Potter, 2008; Wygal and Goebel, 2012).

Given the Diuktai culture expansion from Siberia and the earliest Diuktai found at Swan Point in central Alaska, an initial entry into Eastern Beringia by Diuktai-derived groups at around 15,000—14,000 cal yr BP is reasonable. These data are inconsistent with the 9000 additional years of occupation predicted by the Beringian Standstill model. Any such long period of isolation prior to 15,000—14,000 cal yr BP must have occurred in Asia.

One of the richest concentrations of late Pleistocene sites in the Americas is found in the middle Tanana valley, a tributary of the Yukon River (Fig. 1). Over the last 15 years, we have focused on this relatively small region with intensive systematic surveys and targeted excavations (Potter et al., 2013). Investigations have revealed robust patterning among technology, subsistence, and land use in this region (see also Holmes, 2011; Powers et al., 1983; Wygal and Goebel, 2012; Yesner, 1998), considered in the next section.

2.3. Eastern Beringian site data

Eastern Beringian sites discovered in the Yukon basin are generally deeply buried, and multiple components are situated in well stratified loess contexts. Two components are older than 14,000 cal yr BP (Swan Point CZ4, Little John sub-paleosol), while 11 date between 14,000—13,000 cal yr BP, associated with the Eastern Beringian tradition, Chindadn phase (incorporating the Nenana Complex) (see Holmes, 2011 for discussion). In addition, 38 components date between 13,000—10,000 cal yr BP, associated with the Denali complex. These 51 components have offered excellent avenues to explore Beringian adaptive strategies (Halffman et al., 2015; Potter et al., 2013, 2014). As various elements of this research have been previously published by our team and others, we will focus here on those site-specific results that bear on broad regional

adaptations and their implications for colonization strategies.

Faunal resource procurement for these earliest Beringians is clearly focused on large ungulates, primarily bison (*Bison priscus*) and wapiti (*Cervus canadensis*), found in abundance at numerous sites (Swan Point, Broken Mammoth, Mead, Upward Sun River [USR], etc.) as well as caribou (*Rangifer tarandus*), but also incorporating small mammals (particularly hare and ground squirrel), waterfowl and other birds, and fish (Lanoe and Holmes, 2016; Potter, 2008, 2011; Yesner, 1998). Several of us have published recently on genetic and isotopic analyses of USR salmon exploitation dated to 11,500 cal yr BP (Halffman et al., 2015). This represents the earliest human use of anadromous salmon in the New World. USR's location ~1400 km from the modern outlet and glacial and paleogeomorphology along the lower stretches of the Yukon River suggest that salmon were present along large east-west flowing rivers in Beringia and likely were also available earlier in the late Pleistocene (Halffmann et al., 2015). The earliest known Beringian occupation, Swan Point CZ4b (~14,200 cal yr BP) provides evidence of mammoth and horse exploitation, along with waterfowl. This subsistence base is consistent with the Diuktai culture record in Western Beringia and Siberia (Goebel, 2002; Goebel and Potter, 2016a,b; Pitulko et al., 2016).

Technology in Eastern Beringia also shows similarities with the earlier and coterminous Diuktai culture in Siberia. Swan Point CZ4b technology, while unique for Eastern Beringia, is typical for Western Beringia and Siberia, characterized by microblades produced by the Yubetsu technique and burins, essential for organic tool fabrication (Dikov, 2003; Gomez-Coutouly, 2012; Holmes, 2011; Mochanov, 2009). Lanoe and Holmes (2016) interpret Swan Point CZ4b as a specialized workshop for the production of organic based tools, e.g., osseous projectiles with microblade insets. Swan Point is part of "an ancient cultural system that was widespread across greater Beringia" (Holmes, 2011:188). Technology changed at Swan Point by CZ4a (~13,300—13,100 cal yr BP) and CZ3 (~12,700—11,500 cal yr BP), with less emphasis on microblades (produced through Campus technique rather than Yubetsu), and much more on bifacial technology (Hirasawa and Holmes, 2017; Holmes, 2001, 2008, 2011). Faunal remains indicate changing subsistence, from mammoth and horse (now locally extinct) to bison and wapiti, common in other Bølling-Allerød age sites in the region (Lanoe and Holmes, 2016; Potter, 2008).

The East Beringian tradition, Diuktai phase represents the best evidence we have for human migration into the North American continent via the Bering land bridge. Evidence for an earlier migration, by either interior or coastal routes, is lacking. For the period following this earliest East Beringian cultural phase (~13,500—12,000 cal yr BP), there are two different interpretations: (1) a single broad technological tradition where land use and mobility patterns structure assemblages (Holmes, 2001; Potter, 2011; West, 1996), termed the East Beringian tradition - Chindadn phase/complex which transitions into the Denali complex around 12,500 cal yr BP, and (2) multiple traditions recognized by presence/absence of microblades and/or small teardrop 'Chindadn' points, variously termed Nenana and Denali complexes (Goebel et al., 1991; Hoffecker et al., 1993). More broadly, given the "link between Clovis and the Upper Paleolithic of North-East Asia" (Straus et al., 2005:521—22) and evidence of Siberian Late Upper Paleolithic northward expansion (Goebel, 2002), Clovis progenitors probably used Siberian Late Upper Paleolithic-related technologies. They innovated biface-fluting and abandoned microblade technology, but retained bifacial, unifacial and blade/bladelet technologies found in both Beringian and early Paleoindian cultural complexes.

We have previously identified substantial patterned variation in technology, subsistence, and seasonal land use throughout the

Tanana basin (Potter et al., 2013), and we summarize the salient points here. Microblades are rare at base camps and lithic workshops, while they are common at logistical hunting camps, defined by a narrow range of weapons and predominantly large prey. Microblades (as proxies for composite points) and bifacial points vary in abundance at other hunting camps, but bison and wapiti appear in nearly all of the hunting sites. This suggests complex relationships between site function, seasonality, and multiple weapon platforms. Overall, we can characterize these Beringians as broad spectrum foragers, though with an emphasis (after 14,000 cal yr BP) on bison and wapiti, both large gregarious lowland ungulates. In these riverine areas near glaciers, the Tanana basin faunal record indicates that resource abundance and variety were greater in riverine bottomlands. Given overall regional physiography, east-west movements are expected along the glacial ice edges.

Taken collectively, economic strategies focused on mammoth, horse, and later bison and wapiti would have facilitated expansion eastward along rivers across Western, Central, and Eastern Beringia. The majority of late Pleistocene components are associated with large interior river bottomlands, indicating the importance of these resources for early hunter gatherers. In contrast, these adaptive strategies do not suggest a coastal origin, and no coastal or maritime technology (e.g., fishhooks, boat parts, or float technology to hunt sea mammals on sea ice or open water) appears in any of the known Beringian sites.

2.4. Obsidian distribution patterns

Geochemically sourced lithic raw materials can be used to evaluate expectations for coastal vs. interior migration routes. An initial coastal migration should result in widespread and early movement/sharing of coastal obsidian and only later movement of interior obsidian. A second expectation for an initial coastal migration is initial movement of coastal obsidian into the interior and later exploitation of interior obsidian. An initial interior migration has reversed expectations of early obsidian exploitation and occurrence. A third expectation is that longer-distance procurement or trade of obsidian should be observed along routes of movement or information exchange. To test these expectations, we compiled all known Eastern Beringian sites older than 9000 cal yr BP with geochemically sourced obsidian and the earliest known uses and distances of known interior and coastal obsidian sources (data largely from Reuther et al., 2011; Speakman et al., 2012; supplemented by data from Risa Carlson, 2012, Roy Carlson, 1994; Dixon, 2001; Moss et al., 1996; Potter et al., 2014; Speakman et al., 2007).

Table 1 and Fig. 2 summarize earliest known use and longest distance for late Pleistocene or earliest Holocene-aged sites (>9000 ^{14}C yr BP, or ~10,200 cal yr BP) (enumerated in Potter, 2008; Potter et al., 2013; Carlson and Baichtal, 2015). Artifacts from four of the seven known (or geographically estimated) interior obsidian sources are found in pre-13,300 cal yr BP occupations, including at Swan Point CZ4, dating to 14,200 cal yr BP. The other three interior sources areused by 11,000 cal yr BP. By comparison, the earliest known use of coastal obsidian sources (n = 3) is dated to 11,600—9000 cal yr BP, about 4900—2300 years *after* the earliest use of interior obsidian. Obsidian from interior sources is very widespread, with evidence of long distance movement, averaging 456 ± 142 km and ranging from 600 to 200 km. Movement of this obsidian likely occurred along east-west oriented river drainages (e.g., Yukon, Tanana, Noatak). Interior obsidian is nevertheless restricted to the area between the Brooks and Alaska mountain ranges, which suggests the extent of the early human colonization of Eastern Beringia. In contrast, movement of coastal obsidian was

Table 1
Eastern Beringian obsidian data summary.

Obsidian Source	Earliest use (cal yr BP)	Longest distance (km) (LP/EH)
Interior Obsidian Sources		
Wiki Peak	13,300	465
Batza Tena	13,300	500
Mount Edziza	11,600	260
Hoodoo Mountain	11,500	600
Group A'[a]	13,300	~200
Group H[b]	14,200	?
Group P[c]	11,070	?
Coastal Obsidian Sources		
Okmok Caldera	9000	150
Suemez Island	11,600	260
Akutan	9000	50

[a] Group A' (likely interior, limited to Yukon watershed, source likely near Gulkana).
[b] Group H (likely interior, limited to the Tanana watershed).
[c] Group P (likely interior, limited to the Yukon watershed and northern Alaska — geochemically similar to Hoodoo Mountain).
Adapted from Reuther et al., 2011; Speakman et al., 2012

much more restricted, averaging 153 ± 105 km, and ranging from 260 to 50 km. No coastal obsidian was found substantially inland, nor was interior obsidian found in coastal settings during this time period. Given the substantial age differential, it is also noteworthy that no coastal obsidian was transported and no inferred trading networks were established between hypothetical early coastal populations and related (or other) groups in adjacent interior regions.

In sum, the obsidian data indicate early exploitation of interior obsidian which was widely distributed throughout interior Eastern Beringia along east-west trending drainages, and not transported within north-south trending Pacific seaboard drainages (e.g., Susitna, Copper) or into coastal areas. The expectations for an initial coastal occupation and later expansion into the interior are rejected and the expectations for an initial interior occupation and later expansion to the coast are supported.

3. Colonization route evaluations

The recent accumulation of relevant archaeological, geological, paleoecological, and genetic data allows for more detailed investigations into the nature of the colonization of northern North America, i.e., going beyond educated guesses and perceived mythologies of routes to rigorous testing of multiple hypotheses using substantive data. Both the routes and the timing of colonization need to be critically evaluated based on the quality of data and on the strength of the positive evidence (Erlandson, 2013; Mandryk, 2004; Mandryk et al., 2001).

Below, we briefly summarize the evidence for the two main hypothetical routes (coastal and interior) that humans may have used in the Pleistocene to move from Northeast Asia through Beringia to central North America south of the ice sheets. As others have often noted, there are three main lines of inquiry to establish a route as viable: (1) were there substantial barriers that would have impeded human migration (e.g., presence of massive glaciers or proglacial lakes blocking mountain valley passes or coastal margins; Mandryk et al., 2001; Clague et al., 2004; Pedersen et al., 2016); (2) was there sufficient biological productivity to support human populations (Mandryk et al., 2001; Surovell, 2003; Erlandson et al., 2015); and (3) did the earliest colonizers have the technology to either extract resources from these areas or to move freely and without substantial risk (e.g., efficient cultural adaptations to high-latitude marginal environments, open water boating technology, or sea mammal hunting technology); Dixon,
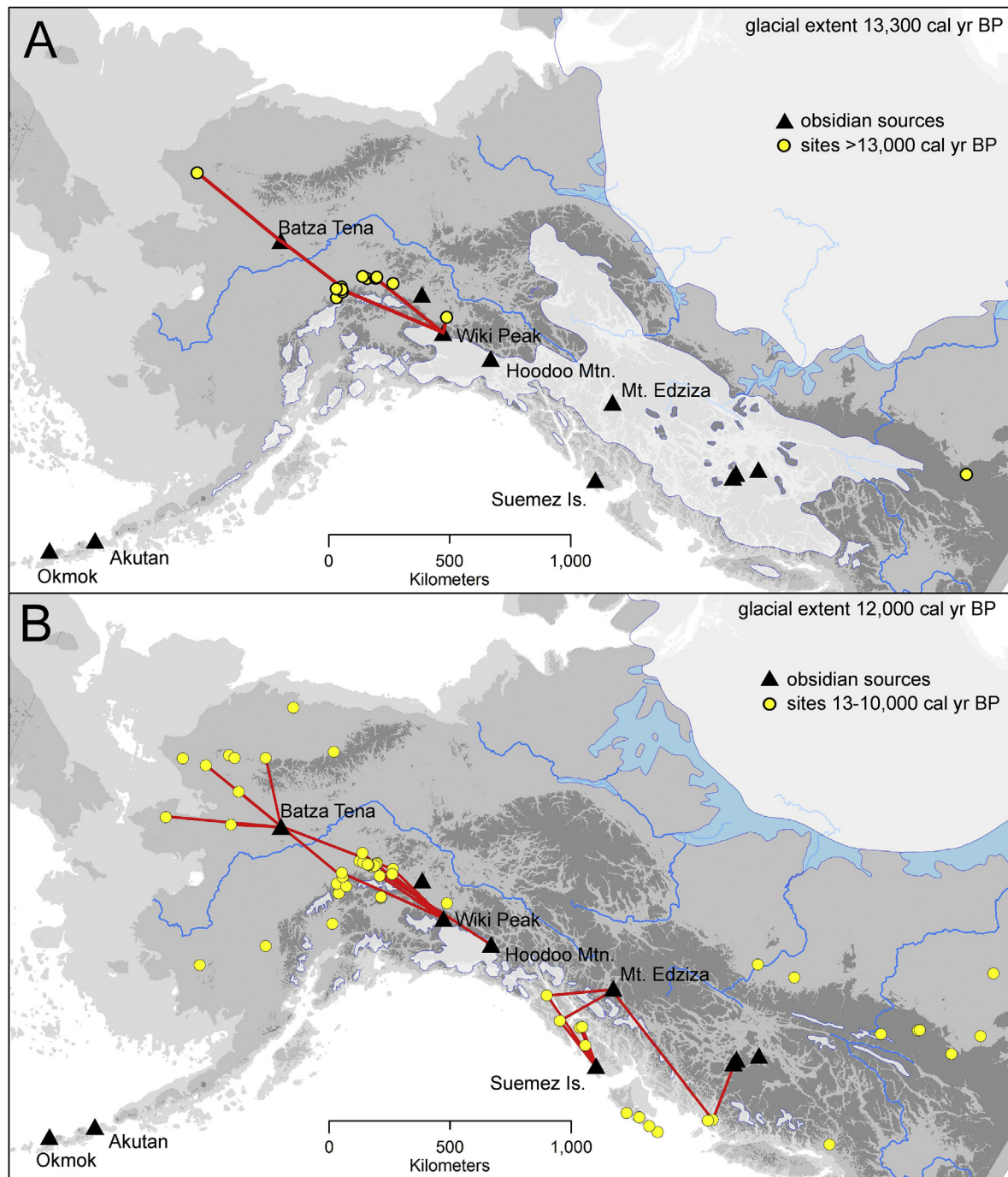
Fig. 2. Obsidian distribution from known sources (A) for sites >13,000 cal yr BP (n = 15), (B) for sites between 10,000—13,000 cal yr BP (n = 78). Note: no known uses of Okmok and Akutan obsidian during this period. Glacial ice extent from Dyke et al. (2003).

2001; Erlandson et al., 2015)?

Discussions on the issues of the ecological viability for both routes mirror each other: when does ice recede, when do plant and animal communities become established to provide food and fuel resources for humans? We review archaeological, geological and ecological data pertinent to the three lines of inquiry mentioned above (see Fig. 1).

3.1. Interior route (Ice Free Corridor)

Researchers have long debated the chronology and habitability

of the Ice Free Corridor (IFC) (e.g., Fladmark, 1979; Burns, 1996; Mandryk, 1996; Mandryk et al., 2001; Driver, 1998; Haynes, 2006; Ives et al., 2013; Dixon, 2013). Some have dismissed the IFC as a "mythological" route (Easton, 1996; Mandryk, 2004), but as Erlandson (2013:128) has so aptly noted, we should not "simply replace one dogmatic paradigm with another". Specific critiques of the IFC as a viable early colonization route for Paleoindian ancestors focus on the apparent late dating of deglaciation and ecological viability, and we have focused on these aspects in this review. We note that researchers have not achieved consensus on the exact timing of these processes (see Ives et al., 2013:162, who argued that

populations could have occupied the IFC at 13,500 cal yr BP). Freeman (2016) also identifies ambiguities in the current data, including interpolation of ice margins where we lack data and non-contemporaneous coalescence of Cordilleran and Laurentide ice; and she observes that "[t]he environmental suitability of the corridor need not be restricted to hunters pursuing late Pleistocene megafauna nor require a prairie landscape free of ice" (2016:53). In view of these recent article-length treatments of the archaeology of the region (Ives et al., 2013; Freeman, 2016), we have restricted our attention to the geochronology of deglaciation and earliest biological data.

The most recent attempt at a comprehensive integration of radiocarbon and geomorphic data to map retreat of the Laurentide Ice Sheet (LIS) and the Cordilleran Ice Sheet (CIS) is by Dyke (2004) and Dyke et al. (2003). Their data indicate that the corridor opened (i.e., the LIS and CIS were no longer coalesced) by 15,600–14,800 cal yr BP, at the latest. Given the significance of the IFC, the dating has been a topic of continued investigation and revision.

Ice retreat was time-transgressive. The corridor opened zipper-like from the north and from the south. In the northern Yukon, lakes dammed by the Laurentide ice sheet were draining by ~16,545 cal yr BP (Table 2: Kennedy et al., 2010), establishing a minimal date for initial retreat of the LIS in the north.

Dating the onset of CIS retreat has yet to be established (see Dawe and Kornfeld, this volume). Dates on erratics along the Rocky Mountain front in southwestern Alberta using cosmogenic isotopes suggest that the LIS reached its maximum position, and an absolute upper age limit for the IFC, in the range of 17.0–16.0 kya (Jackson et al., 2008, Table 5; Margold et al., 2014; Stroeven et al., 2010, 2014). Some cosmogenic isotope ages suggest the possibility of exposure of highlands on mountain passes in the Yukon and western Alberta being exposed as early as 19.3 to 18.5 kya (Jackson et al., 1999a,b; Jackson et al., 2008; Stroeven et al., 2010, 2014).

When the LIS and CIS were no longer in contact, the result was a relatively narrow "bottleneck" area, roughly over the present-day upper Peace River of west-central Alberta and east-central British Columbia. As the ice retreated, a series of proglacial lakes formed and drained along the Laurentide ice front. Glacial Lake Peace developed in this bottleneck area. This narrowest part of the Ice Free Corridor still spanned considerable area as mapped by Dyke et al. (2003) (see below): ~110, 120, and 240 km wide at 14,800, 13,800, and 13,300 cal yr BP (prior to Clovis) respectively. The ice-free area expanded after 13,300 cal yr BP: 430 km wide at 12,800 cal yr BP and 700 km wide at 12,500 cal yr BP (Dyke et al., 2003). OSL and IRSL dates of dunes in the southern half of the IFC (Wolfe et al., 2004, 2007; Munyikwa et al., 2011, 2017) show that the opening of the IFC was considerably earlier than indicated by Dyke et al. (2003, 2004). In a summary of the dating (Munyikwa et al., 2017, Table 2) 31 samples from 13 dune fields provide mean ages at or older than Clovis time (see Table 2). Reconstructions of the IFC landscape in the bottleneck area by Munyikawa et al. (2017) indicate a 300-150 km and 600-400 km-wide corridor, north and south of Glacial Lake Peace, respectively, at ~15 kya, and 300 km to >600 km wide, north and south of Glacial Lake Peace, at ~14 kya.

Separation of the ice sheets is, however, only part of the Ice Free Corridor hypothesis. The other critical issue, from the standpoint of human migration, is viability of the corridor. Were resources and conditions available to support human populations? Were there physical impediments to travel such as large proglacial lakes? A recent paper by Pedersen et al. (2016) has provided significant data bearing on these problems. These authors argue that the opening of the IFC was "followed by regional inundation below waters of Glacial Lake Peace for perhaps up to 2000 years" (Pedersen et al., 2016:48). They studied cores from two lakes thought to be

remnants of Glacial Lake Peace and interpret the coring data to suggest that the larger GLP drained, the study lakes became isolated, and regional vegetation was established no earlier than ~12,600 cal yr BP. Only then (i.e., in post-Clovis times) was the IFC available for human movement between Beringia and the interior of North America. These interpretations led Pedersen et al. (2016, p. 48) to conclude that "Clovis people … must have descended from a population that entered the Americas via a different route than the ice-free corridor."

While they employed a rigorous analytical suite of eDNA and paleoecological analyses and we do not disagree with their post-12,600 cal yr BP interpretations, several considerations raise doubts about the pre-12,600 cal yr BP chronology and landscape evolution of the IFC proposed by Pedersen et al., 2016. They base their interpretations of the origins of Glacial Lake Peace and the evolution of an open landscape on work by Hickin et al. (2015). That lake reconstruction is hampered by very limited numerical age control. Hickin et al. (2015) report only two OSL dates, both pertaining to what they call Phase II of GLP. The dates are 16.0 ± 2.5 kya and 14.2 ± 0.5 kya (Table 2) and they use those dates to suggest that is the age range of GLP Phase II. However, those two dates overlap at one standard deviation and thus cannot resolve the lake chronology. Further, the series of maps illustrating the evolution of the lake (Hickin et al., 2015, Fig. 10), while well-grounded on field data, cannot be accepted as an accurate chronology.

The radiocarbon date of ~12,600 cal yr BP reported by Pedersen et al. (2016) was determined on terrestrial plant remains that rested on laminated lake clays (compare with Fig. 1D). The clays are interpreted as GLP Phase IV (~13.0 kya) but there is no way to link those lake deposits directly to any phase of GLP or determine if they are GLP or post-GLP sediments deposited in lakes that evolved from remnants of GLP. Indeed, below the laminated clays at Charlie Lake is a layer of proglacial gravel. Such a deposit is an indicator of a subaerially exposed landscape with active alluviation, i.e., there was no lake in the immediate area. To the south, in Boone Lake, White et al. (1985) recovered wood (poplar) from the base of organic-rich sediments that rested on lake clays. The resulting date of ~13,555 cal yr BP (Table 2) shows that the subaerially exposed landscape of the IFC "bottleneck" was forested at least ~1000 years sooner than proposed by Pedersen et al. (Fig. 1C). Further, a comparison of maps (White et al., 1985: Fig. 1 vs. Hickin et al., 2015: Fig. 10E,F,G) indicates that the Boone Lake area was exposed as GLP III evolved into GLP IV.

Some proglacial lakes were certainly present in the area but their chronology and extent over time is unknown. The shoreline mapping of GLP by Hickin et al. (2015) shows that even at lake maximum, some areas along the margins were dry and ice-free. GLP IV did not cover the bottleneck area from ice front to ice front (Hickin et al., 2015: Fig. 10G), and the lakes themselves would have been frozen part of every year so they would have been crossable during the winter.

Entrenchment of the Peace River also provides clues to the evolution of Glacial Lake Peace and the IFC landscape. Along the Peace River ~25 km southwest of Charlie Lake, an alluvial fan built up on a terrace of the river (Jull and Geertsema, 2006). This fan could not form until sometime after final drainage of the glacial lake, stream incision, and terrace formation (Hartman and Clague, 2008). Charcoal-rich sediment in the fan indicates that it had formed by at least ~12,500 cal yr BP and possibly is as old as ~16,300 cal yr BP (Table 2). That interpretation is supported by OSL dating of dunes near and south of the GLP area. The work by Munyikawa et al. (2017) indicates that GLP drained after ~15 kya and that the IFC landscape in the bottleneck area was lake-free by ~14 kya.

Wolfe et al. (2004) and Munyikawa et al. (2017) dated relict

Table 2
Dating relevant to the earliest opening of the Ice Free Corridor (>12.9 kya).

Location	Dating method (material)	[14]C age BP	Calibrated or Calendar years[a]	References
Northern Deglaciation				
Yukon	[14]C plant macrofossils	13,710 ± 40 Beta218602	~16,545 cal yr BP (16,650—16,414)	Kennedy et al., 2010
NWT	[14]C bison bone Retreat of LIS	11,830 ± 45 OxA-18549	~13,655 cal yr BP (13,716—13,597)	Zazula et al., 2009
B.C/Alberta Peace River	Wood Contact between till (below) & glaciolacustrine sediments (above)	13,970 ± 170 TO-2742	~16,944 cal yr BP (17,206—16,657)	Catto et al., 1996 also discussed by Hartman and Clague 2008
Yukon — MacKenzie Mountains (CIS)	Cosmogenic ([10]Be; boulders/cobbles from moraines)		19.3 ± 1.8 to 15.0 ± 1.4 kya (no corrections for snow shielding or surface erosion)	Stroeven et al., 2010
Yukon — Pelly River (CIS)	Cosmogenic ([10]Be; boulders/cobbles from moraines)		13.3 ± 1.2 to 11.2 ± 1.0 kya (no corrections for snow shielding or surface erosion)	Stroeven et al., 2010
Yukon-Selwyn Lobe (CIS)	Cosmogenic ([10]Be; boulders/cobbles from moraines)		14.5 ± 1.3 to 11.7 ± 1.2 kya (no corrections for snow shielding or surface erosion)	Stroeven et al., 2010
Yukon — Thulsoo Mountain region; Coastal Mountain Lobe? (CIS)	Cosmogenic ([10]Be; boulders/cobbles from moraines)		17.7 ± 1.6 to 15.7 ± 1.5 kya (no corrections for snow shielding)	Stroeven et al., 2014
Southern Deglaciation, North/Northwest of "Bottleneck"				
High Level, AB	IRSL eolian sand		13.4 ± 1.2 kya	Wolfe et al., 2007
Fontas River, BC	IRSL eolian sand		13.9 ± 1.2 kya	Wolfe et al., 2007
Ft McMurray, AB	OSL eolian sand		14.0 ± 1.0 kya	Munyikawa et al., 2017
Glacial Lake Peace Area, in the "Bottleneck"				
Watino, AB	IRSL eolian sand		12.9 ± 0.8 kya	Wolfe et al., 2004
Grand Prairie, AB	IRSL eolian sand		13.7 ± 1.0 kya	Wolfe et al., 2004
	IRSL eolian sand		14.9 ± 1.0 kya	Wolfe et al., 2004
	IRSL eolian sand		14.2 ± 0.9 kya	Wolfe et al., 2004
Landforms	OSL sandy strand lines		14.2 ± 0.5kya (min) 16.0 ± 2.5kya (max)	Hickin et al., 2015
Boone Lake, AB	[14]C plant macrofossils	11,700 ± 260 SFU 223	~13,555 cal yr BP (13,800—13,250)	White et al., 1985
Charlie Lake, BC	[14]C plant macrofossils	10,635 ± 50 OxA-32358	~12,600 cal yr BP (12,668—12,573)	Pedersen et al., 2016
Chetwynd, BC	[14]C bison bone	11,240 ± 70 OxA-11274	~13,108 cal yr BP (13,173—13,046)	Shapiro et al., 2004
Bear Flat, AB	[14]C Taiga vole	12,567 ± 79 AA46352	~14,868 cal yr BP (15184—14371)	Hebda et al., 2008
Bear Flat, AB	[14]C Taiga vole	11,507 ± 72 AA46353	13,351 cal yr BP (13478—13351)	Hebda et al., 2008
Southern Deglaciation, South/Southwest of "Bottleneck"				
Decrene, AB	OSL eolian sand		14.8 ± 1.6 kya	Munyikawa et al., 2017
	OSL eolian sand		13.0 ± 1.4 kya	Munyikawa et al., 2017
	IRSL eolian sand		14.8 ± 0.9 kya	Wolfe et al., 2004; Munyikawa et al., 2017
Chisholm, AB	IRSL eolian sand		15.3 ± 0.8 kya	Wolfe et al., 2004; Munyikawa et al., 2017
Hondo, AB	OSL eolian sand		15.4 ± 1.1 kya	Munyikawa et al., 2017
	OSL eolian sand		14.9 ± 1.1 kya	Munyikawa et al., 2017
	OSL eolian sand		13.2 ± 1.1 kya	Munyikawa et al., 2017
	OSL eolian sand		13.3 ± 1.2 kya	Munyikawa et al., 2017
	OSL eolian sand		12.9 ± 1.3 kya	Munyikawa et al., 2017
	OSL eolian sand		14.3 ± 1.0 kya	Munyikawa et al., 2017
	OSL eolian sand		13.8 ± 1.0 kya	Munyikawa et al., 2017
	OSL eolian sand		12.9 ± 1.4 kya	Munyikawa et al., 2017
	OSL eolian sand		13.1 ± 1.5 kya	Munyikawa et al., 2017
	IRSL eolian sand		14.2 ± 0.7 kya	Wolfe et al., 2004; Munyikawa et al., 2017
Ft Assiniboine, AB	OSL eolian sand		14.6 ± 1.7 kya	Munyikawa et al., 2017
	OSL eolian sand		15.0 ± 1.3 kya	Munyikawa et al., 2017
	OSL eolian sand		13.1 ± 0.9 kya	Munyikawa et al., 2017
	IRSL eolian sand		14.5 ± 1.0 kya	Wolfe et al., 2004; Munyikawa et al., 2017
Nelson Lake, AB	IRSL eolian sand		14.5 ± 0.9 kya	Wolfe et al., 2004; Munyikawa et al., 2017
Windfall, AB	IRSL eolian sand		15.7 ± 1.6 kya	Wolfe et al., 2004; Munyikawa et al., 2017
Holmes Crossing, AB	OSL eolian sand		18.3 ± 1.2 kya	Munyikawa et al., 2017
	OSL eolian sand		13.5 ± 1.0 kya	Munyikawa et al., 2017
	OSL eolian sand		15.3 ± 1.3 kya	Munyikawa et al., 2017
	IRSL eolian sand		14.9 ± 1.0 kya	Wolfe et al., 2004; Munyikawa et al., 2017
Lac La Biche, AB	OSL eolian sand		14.7 ± 1.6 kya	Munyikawa et al., 2017

Table 2 (continued)

Location	Dating method (material)	[14]C age BP	Calibrated or Calendar years[a]	References
Alberta, southwestern (LIS)	Cosmogenic ([36]Cl; erratics)		15.5 ± 0.4 to 11.0 ± 0.6 kya (erosion correction in Jackson et al., 2008) (no snow cover correction- assumed to be minimally covered)	Jackson et al. 1997, Jackson et al., 2008
Alberta, western (LIS)	Cosmogenic ([36]Cl; erratics)		18.5 ± 0.9 to 12.3 ± 2.5 kya; (zero erosion age; snow correction)	Jackson et al., 1999, Jackson et al., 2008
Telkwa Range (CIS), central BC	Cosmogenic ([10]Be; erratics)		12.4 ± 0.7 kya (weighted average of dates with snow shielding correction)	Margold et al., 2014
Marble Range (CIS), southern BC	Cosmogenic ([10]Be; erratics)		15.3 ± 1.1 kya (weighted average of dates with snow shielding correction)	Margold et al., 2014
Calgary, Alberta	[14]C bison bone	11,300 ± 290 RL-757	~13,160 cal yr BP (13,421—12,872)	Shapiro et al., 2004
Edmonton, Alberta	[14]C bison bone	11,255 ± 45 UCIAMS 117399	~13,114 cal yr BP (13,145—13,071)	Heintzman et al., 2016
Vauxhall, Alberta	[14]C bison bone	11,620 ± 150 OxA-14273	~13,450 cal yr BP (13,582—13,286)	Burns 2010; Ives et al., 2013
Edmonton, Alberta	[14]C bison bone	11,620 ± 170 AECV:1203c	~13,455 cal yr BP (13,608—13,270)	Burns 2010; Ives et al., 2013

[a] Dates expressed as cal yr BP and two sigma range for radiocarbon dates and mean calendar years ago and one sigma range for OSL and cosmogenic dating.

dunes in and around the area of GLP. Their resulting dates range from ~14.9 to ~13.5 kya, suggesting presence of at least locally dry landscapes (Fig. 1A—C). At ~14.5 kya, the two ice fronts may have been ~300 km apart in central Alberta (Table 2: Wolfe et al., 2004, Fig. 4A). To the northeast in northern Alberta, Wolfe et al. (2007) date relict dunes to ~13.4 kya (Table 2). That position would establish an IFC north of GLP at ~350 km wide, broader than the mapping by Dyke et al. (2001).

Food and fuel limitations are the other key limitations to human migration. Dating suggests that the northern IFC was viable with plant and animal resources by ~13,560 cal yr BP (Table 2). The southern end of the corridor was wide enough and sufficiently well drained to contain dune fields by ~15 kya (Table 2). Horse and bison were present in the Edmonton area by ~13,450 cal yr BP (Table 2). Loehr et al. (2006) suggest that sheep were sustained in ice-free refugia during the LGM in the MacKenzie Mountains and northeastern British Columbia and that these regions allowed gene flow between *Ovis dalli* and *Ovis canadensis*. Others have also suggested refugia for particular angiosperms on nunataks within the CIS in Alberta throughout the LGM (*Packera* sp.: Golden and Bain, 2000).

In the Peace River area Catto et al. (1996) recovered wood resting on glacial till and covered with lake deposits. The resulting date of ~17,000 cal yr BP is a time when the LIS and CIS were almost fully coalesced, according to the ice sheet reconstructions by Dyke (2004). If true, it still indicates that old wood could have been available on the recently deglaciated landscape. Similarly, the Bear Lake fan on an alluvial terrace of the Peace River (Jull and Geertsema, 2006) provides evidence of tree cover in the area at ~16,300 cal yr BP (Table 2) and detrital wood charcoal as old as ~36,000 cal yr BP. In addition, Hebda et al. (2008) report two radiocarbon ages on Taiga vole (*Microtus xanthognathus*) remains, from what is interpreted as fox digesta, in the Bear Flat fan ranging between 15,180—14,370 and 13,480—13,350 cal yr BP (Table 2). Pollen and spore assemblages taken from immediately surrounding the remains are indicative of an open landscape (Hebda et al., 2008:617), possibly with scattered trees and shrubs.

We agree in part with Pedersen et al. (2016) that the DNA-based reconstruction of steppe vegetation with mammoth and mastodon at ~12,600 cal yr BP provides a *minimum* age for a viable landscape. The vegetation system must establish itself before a viable

megafauna population can survive. The megafauna will have had a much more limited and specific diet than humans. Similarly, Charlie Lake Cave, at the south end of Charlie Lake, where the ~12,600 cal yr BP plant materials were recovered, produced remains of vertebrate faunas and human occupation dating to ~12,600 cal yr BP and a little older (Driver et al., 1996; Fladmark et al., 1988; Shapiro et al., 2004). These are unlikely to have been the first humans and other vertebrates in the area.

As a follow-up to mapping the ice retreat chronology, Dyke (2005) used the paleobotanical and terrestrial vertebrate data that accompanied the radiocarbon data set. His mapping data indicate that tundra persisted throughout the IFC (herb tundra in the north and shrub tundra in the south) at ~13,900 cal yr BP (Fig. 1B).

This raises a broader question of the rates at which a deglaciated landscape becomes vegetated. In a study of modern ice retreat, Sharp (1958) estimated establishment of spruce forest in front of the retreating Malaspina Glacier in Alaska at 30—50 years. Chapin et al. (1994) found comparable results for Glacier Bay, Alaska. This may be unusually rapid given the maritime setting. More appropriate for the IFC is revegetation of the southern margin of the LIS. In eastern Wisconsin the Green Bay lobe of the LIS readvanced at ~14,800 cal yr BP (Syverson and Colgan, 2011). Following retreat of the ice, northeast Wisconsin was revegetated by the Two Creeks Forest ~13,800—13,500 cal yr BP. The area was a mixed taiga-tundra environment ~14,500—13,900 cal yr BP that evolved into the taiga forest (Rech et al., 2012). Wood, pollen and coleopterans show presence of *Picea*, Cyperaceae, and sedge (Maher and Mickelson, 1996). The area was subsequently buried by another advance, producing the well-known buried forest. Similarly, the Hebior and Schaefer mammoth sites in southeast Wisconsin lay within spruce parklands with sedge ~170 km from the ice front at ~12,400 ^{14}C yrs BP (Overstreet and Kolb, 2003). These data show that the landscape exposed by the retreating LIS could have been revegetated with herbaceous tundra within a few hundred years and by forests well within 1000 years and likely much sooner. This evidence accords well with the paleo-vegetation data noted above.

A freshly deglaciated IFC landscape with stagnant ice, katabatic winds, shifting drainages, large bodies of water, and perhaps surges of meltwater has been viewed as uninhabitable. However, winds

and impassable water were likely only seasonal problems. Moreover, the first inhabitants of interior Eastern Beringia may have been uniquely adapted among late Pleistocene hunter-gatherers to deal with whatever rigors the IFC offered. In our view, the IFC chronology and environmental reconstruction easily permit East Beringian tradition populations to expand south between ~14,000–13,000 cal yr BP.

Other objections to the IFC as an early colonization route are based on ambiguous data or assumptions. Recent research on bison phylogeography provides evidence of a "habitable and traversable corridor by at least 13,000 cal yr BP, just before the first appearance of Clovis technology in interior North America" (Heintzman et al., 2016:8057). This analysis provides only a minimum date for bison and suitable grazing habitats throughout the corridor, rather than direct evidence for how early the region was ecologically viable. Humans may also have exploited other non-bison resources in the IFC (Freeman, 2016), including sheep, which have been found in refugia between Laurentide and Cordilleran ice sheets (Loehr et al., 2006). Others have pointed out the lack of well-dated sites in the IFC prior to ~12,500 cal yr BP (Dixon, 2011). Site visibility may be affected by sampling as well as periglacial processes (e.g., rapid aeolian remobilization, active downcutting, proglacial lake outbursts) (Driver, 1998; Ives et al., 2013; Munyikawa et al., 2017), and we note that this absence is mirrored by the lack of well-dated sites of similar age along the coastal route (see below). The relatively late occurrence (~12,500 cal yr BP) of fluted points in Beringia (Alaska) has led some to argue for a south to north migration or diffusion of fluting technology through the IFC area (Goebel et al., 2013). While we agree with this interpretation of timing and directionality, we note that it does not directly bear on earlier potential use of the corridor.

3.2. North Pacific Coastal Route

Since Fladmark (1979) popularized the North Pacific Coastal Route, many have written on the potential or necessity of an early post-glacial coastal colonization to account for the oldest archaeological material south of the ice sheets. The more widespread acceptance of Monte Verde's antiquity in the 1990s brought the coastal migration hypothesis to the forefront of research on the Pleistocene human colonization of North America (Dillehay, 1997; Meltzer, 2009). We limit our summary to the southern coastal zones of Alaska and British Columbia. The exposed landscape along this coast was a relatively narrow strip along the continental shelf, some areas relatively flat and others with considerable relief (Clague et al., 2004; Dickinson, 2011).

The viability of the coastal route is partially dependent on the state of deglaciation; most arguments for a coastal migration require the onset of deglaciation and minimization of ice barriers. Along the southwestern and southcentral Alaskan coastlines glacial recession was also time-transgressive, occurring throughout the late Pleistocene and early to middle Holocene, with deglaciation beginning ~19,000–17,000 cal yr BP (Mann and Hamilton, 1995; Mann and Peteet, 1994; Reger and Pinney, 1996; Davies et al., 2011; Misarti et al., 2012). Both Reger and Pinney (1996) and Davies et al. (2011) have shown mixing of fresh and marine water in the Gulf of Alaska region in southcentral Alaska by 19,000–16,600 cal yr BP, marking the beginning of deglaciation. Some marine glaciers in northern Gulf of Alaska appear to have retreated onto land or deeper into fjords between 15,500–14,700 cal yr BP (Crossen et al., 2010; Davies et al., 2011). On the southeast Alaskan mainland, glaciers receded between 16,000–14,000 cal yr BP, considerably later than the outer coast of British Columbia, where deglaciation began ~19,000 cal yr BP, the eastern section of the Dixon Entrance free of ice by ~16,400 cal yr BP

(Shugar et al., 2014).

Chronological data on late Pleistocene and early Holocene glacial retreat along the southwestern and southcentral Alaskan coastlines, and in key areas of southeastern Alaska such as the outer Alexander Archipelago, remain sparse and it is unclear if there is an unimpeded linear coastal corridor to the areas south of the CIS and LIS by 15,000 cal yr BP (Erlandson et al., 2007, 2015). Even if there was not continuous land exposure along the continental shelf, several geological and paleontological studies have established areas of coastal refugia in southeastern Alaska and British Columbia. Bears re-appear early in the late Pleistocene in cave deposits, the oldest on Haida Gwaii dated to 17,680–17,160 cal yr BP and on Prince of Wales Island at 14,840–14,090 cal yr BP, followed by open-landscape species such as caribou and fox (Heaton and Grady, 2003; Ramsey et al., 2004). Predator marks on sea mammal bones in the caves on Prince of Wales, along with the inferred speed of expansion by various mammal, bird, fish, plant (including trees) and insect species, have led to the assumption that there must have been nearby refugia harboring many species during the LGM. A recent flurry of phylogeographic studies (see Shafer et al., 2010; Yamamoto et al., 2014 for summaries) are now attempting to combine genetic data with species distribution maps to predict potential locations for refugia (Sawyer and Cook, 2016). Efforts to pinpoint locations have focused on the outer uplifted coastal plains of the Alexander Archipelago and the coastal plain under Hecate Strait, by Haida Gwaii (Carrara et al., 2007; Hetherington et al., 2004). Cores from Hecate Strait appear to indicate some terrestrial vegetation between at least 17,370 and 14,570 cal yr BP; comparable attempts to define extents of refugia or gather paleoenvironmental data in southeast Alaska are lacking despite evidence in marine cores of fresh-water to salt-water transitions following the collapse of the forebulge (Lacourse et al., 2005; Barron et al., 2009; Addison et al., 2010). While relative sea-level change has greatly complicated investigations of these areas, there are a number of islands that Carrara et al. (2007) connected to refugia that could be investigated (by lake coring) for LGM refugium vegetation in southeast Alaska.

On Haida Gwaii there is evidence for early deglaciation and vegetation; sediments from marine cores and from sections along wave cut-cliffs provide a vegetation record beginning circa 18,000 cal yr BP on northeastern Graham Island (Mathewes et al., 1985), and around 14,000 cal yr BP on Hippa Island to the northwest (Lacourse et al., 2012). A core from Dogfish Bank (on the continental shelf between Haida Gwaii and mainland British Columbia) also indicates that at least some portions of the shelf were exposed and partially vegetated between 17,370 and 14,570 cal yr BP (Lacourse et al., 2005). In southeast Alaska data are more limited. The earliest record of post-LGM vegetation at 15,400 cal yr BP is from a core on Pleasant Island near Glacier Bay; the earliest dates from Prince of Wales Island and Mitkof Island are considerably later (13,700 cal yr BP and 12,900 cal yr BP, respectively) (Hansen and Engstrom, 1996; Ager and Rosenbaum, 2009; Ager et al., 2010). If refugia did exist, these lake cores likely reflect localized deglaciation and succession; refugia and deglaciating islands were initially populated with herb-shrub tundra and pockets of forest, along with associated animal species (e.g., caribou, deer, bear, fox) that would have been particularly familiar to terrestrial-focused hunter-gatherers.

Concerns about the ecological stability and available resource base of the IFC have not been similarly voiced for the coastal migration route; comparable scrutiny should be applied to both potential routes. In light of how poorly the extent and continuity (or patchiness) of coastal refugia has been established, it is difficult to assess their stability and carrying capacity (Surovell, 2003). Species isolated during the LGM would have been suffering the effects of

genetic isolation and may have been at their 'ecological limits' (Hope et al., 2015), though upon expansion from refugia this could have been mitigated through intermixing with recolonizing populations from the north and south. One potentially stable resource for humans was anadromous fish, which appear to have survived in refugia based on phylogeographic studies (Hastings, 2005; Yamamoto et al., 2014). Salmon have been observed colonizing watersheds within 15 years of their deglaciation, which suggests these species could have expanded rapidly from refugia (Milner and Bailey, 1989). Unlike the more spatially limited populations of terrestrial mammals in refugia (bears, caribou, etc.), salmon could have been available as a more stable, predictable seasonal resource for early inhabitants of the Northwest Coast. Tracking the arrival of salmon-derived nutrients in cores from nursery lakes should allow determination of the availability of salmon at local scales.

The kelp highway hypothesis, based on the possibility that a pan-Pacific coastal kelp network may have existed during the late Pleistocene, envisions a highly productive marine ecosystem ripe with resources for a coastal-adapted hunter-gatherer population to follow from eastern Asia to the tip of South America (Erlandson et al., 2007, 2015). A niche-based model of one variety of kelp in southern California supports this hypothesis at a regional level, predicting peaks in kelp productivity immediately following the LGM (Graham et al., 2010). While certain species of kelp can survive even in areas packed with seasonal sea ice (Erlandson et al., 2007), data on kelp productivity at a local scale in periglacial environments complicates the kelp highway hypothesis in northern latitudes, where the kelp highway's existence is most critical. Kelp requires both a rocky substrate and light for survival; studies of modern kelp in periglacial environments suggest that the influence of glacial melt-water (increased inorganic sedimentation, changes in salinity, nitrate levels) reduces both taxonomic richness and abundance in kelp populations (Spurkland and Iken, 2011; Murray et al., 2015). When glaciers were receding, the 'kelp highway' may have been quite patchy.

From the Aleutians to the Gulf of Alaska, geological and paleo-environmental data that suggest land exposure along the continental shelf, and possible refugia for animals and humans, are very limited. Areas of the Alaska Peninsula Glacial Complex (APGC) of the CIS began receding by 17,900 cal yr BP, and pollen, macrofossil and pedologic data from Sanak Island in the eastern Aleutians and Kodiak Island in the Gulf of Alaska show vegetative growth at 17,000—16,300 cal yr BP (Mann and Peteet, 1994; Misarti et al., 2012). Misarti et al. (2012) provide evidence based on a pollen assemblage from a lake core on Sanak Island that represents an herbaceous tundra vegetation (*Artemisia*, *Ericaceae*, *Cyperaceae*, *Salix*, and *Poaceae*) by 16,300 cal yr BP. Mann and Peteet (1994; see also Peteet and Mann, 1994) recorded a sedge peat and willow shrubs present on Kodiak by 17,900 cal yr BP. Ferns became common on southwestern Kodiak Island by 15,500 cal yr BP as temperatures and moisture increased during the Bølling-Allerød (Peteet and Mann, 1994), but they declined with a change to arid and cooler temperatures during the Younger Dryas. On the Kenai Peninsula, peat development began by 14,000 cal yr BP with herbaceous and shrub tundra covering lowlands and mountain sides between 14,200 and 12,800 cal yr BP (Jones et al., 2009; Ager, 2000).

Late Pleistocene faunal evidence indicating viable refugia along the APGC is currently scant, when compared to that of the southeastern Alaska and British Columbia refugium data. Crossen et al. (2010) provide evidence for late Pleistocene marine fauna in a marine embayment near the Bering Glacier around 15,500 cal yr BP, all of which are indicative of a pack ice habitat (ringed and bearded seals and walrus).

Other impedances to consider in the coastal route's viability at northern latitudes are the presence of sea ice and recurrent volcanism. The presence of sea ice is an important factor to consider in the viability of a coastal habitat and the technology and knowledge required to hunt specific types of sea mammals, in addition to hazards for watercraft navigation. Proxies in marine sediment cores used to reconstruct the distribution of sea ice in the northern North Pacific include the presence of sea mammals that favor sea ice habitat, ice-rafted debris, diatoms, and calcareous fossils (e.g., planktonic foraminifera and coccolithophorids).

In southeast Alaska, ringed seal remains in Shuká Kaa Cave date to 16,900—16,200 cal yr BP (Heaton and Grady, 2003); ringed and bearded seals and walrus in southcentral Alaska around the Bering Glacier date to ~15,500 cal yr BP (Crossen et al., 2010). These species are indicative of a pack ice habitat. Along the southern Alaskan coast, ice-rafted debris vanishes in marine core samples abruptly around 14,700 cal yr BP, marking the retreat of glaciers onto land or into sheltered fjords in the Gulf of Alaska region (Davies et al., 2011; Praetorius et al., 2016). Others have tracked diatoms and ice-rafted debris as a proxy for sea-ice, potentially pushing its disappearance into the Younger Dryas (Barron et al., 2009; Addison et al., 2012). Thick perennial ice pack covered the southwestern Bering Sea prior to 17,000 cal yr BP, seasonal sea ice formed by 15,800—15,100 cal yr BP, and by 11,300 cal yr BP the area became ice-free as warmer waters of the Pacific entered the Bering (Sancetta et al., 1985; Caissie et al., 2010). It is currently unclear if the North Pacific waters along the eastern Aleutians were ice-free during the late Pleistocene as surface sea temperatures (SST) increased enough to limit sea ice development between 18,200 and 14,700 cal yr BP in the northwestern North Pacific (Misarti et al., 2012; Sarnthein et al., 2006). However, SST and sea ice development have been shown to be variable across the northern North Pacific and influenced by more local factors including proximity to glacial margins of the Cordilleran Ice Sheet (Addison et al., 2012), and without a proxy record closer to the eastern Aleutians, we should be cautious in inferring entirely ice-free conditions in the late Pleistocene in this region. Though still geographically sparse, the current data on paleo-sea ice distribution suggest that waters in the northeastern portions of the North Pacific, abutting the landmasses of the continental shelf and the CIS, were covered at least seasonally by ice throughout much of the late Pleistocene, possibly into the Younger Dryas.

The potential impact of volcanism on deglaciation, the local ecology and potential late Pleistocene and early Holocene human inhabitants along the coastal route has received little attention in the archaeological literature. Isostatic adjustment appears to have triggered a sequence of volcanic activity in southeast Alaska, which further accelerated deglaciation. A recent analysis of core data from the coast of Chicagof Island suggests up to 22 individual eruptions of the Mount Edgecumbe volcanic field occurred during deglaciation; 19 fall within a peak period from 14,600—13,100 cal yr BP (Praetorius et al., 2016). The spatial extent of associated tephras is not well constrained, though based on other marine cores and terrestrial deposits the affected areas are to the east and north of Mount Edgecumbe. These tephras may have promoted rapid melting of affected glaciers (reflected in oxygen isotope changes that indicate an influx of freshwater during this period) and would have had a direct impact on the ecology of the region.

While the traditional coastal route implies entry to the coast from northeast Asia, another potential entry point to the Northwest Coast of North America is out of the interior, through the southwestern Yukon (Borden, 1975). While Dyke's model estimates the opening of the White Pass area between 13,500 and 13,000 cal yr BP, he lacks data in that particular region (2004). Cosmogenic nuclide ([10]Be) exposure dating of boulders and cobbles from moraines created by a coastal mountain ice lobe indicates that glacial

advance ceased, and retreat possibly began, in higher altitudes around 17.7 and 15.7 kya (Stroeven et al., 2014). Pollen records from lake cores suggest vegetation in the Ruby Mountains by 13,600 and by 12,500 cal yr BP in White Pass itself (Spear and Cwynar, 1997; Bunbury and Gajewski, 2009). These data appear parsimonious with Dyke's model, but while White Pass may have provided a route for early hunter-gatherers into the Northwest Coast or for coastal peoples to return north, it does not appear biologically viable early enough to account for Monte Verde.

Archaeological data attesting to late Pleistocene human occupation, marine mammal hunting and watercraft technology is sparse along a vast majority of the coastal route. As mentioned above, there are no known sites before 9000 cal yr BP along the southern coastal or near-coastal stretches of Eastern Beringia and the AGPC (Davis et al., 2016). Along the Northwest Coast of North America in southeast Alaska and British Columbia, direct archaeological evidence for late Pleistocene human occupation is affected by relative sea-level change: variable isostatic rebound accompanying deglaciation, the collapse of an elevated forebulge along the outer islands, and eustatic sea-level rise. These factors complicate relative sea-level histories, which must be evaluated at local levels (Shugar et al., 2014). However, no sites located along resource-rich rivers in the adjacent interior have been discovered in this region prior to 12,600 cal yr BP.

Where uplifted paleoshorelines have been identified, associated early Holocene sites have been discovered; the oldest sites date to around 10,300 cal yr BP in Alaska and 10,700 cal yr BP in the intertidal zone of Gwaii Hanas (Carlson and Baichtal, 2015; Mackie et al., 2013). Footprints have been reported at an intertidal site on Calvert Island, perhaps dating to 13,000 cal yr BP, though they have yet to be published in a peer-reviewed journal (Koppel, 2016). The identification of a 'hinge' along coastal British Columbia shows promise for earlier sites, as land near the hinge had relatively stable shorelines for around 15,000 years. MacLaren et al. (2015) reported two radiocarbon dates from a charcoal-rich layer in organic sediments from a site on Hunter Island as 13,670—13,450 and 12,860—12,700 cal yr BP, which demonstrate older landforms. Other dates from this site and MacLaren et al.'s (2015) broader survey fit within a more confined time sequence beginning around 11,000 cal yr BP.

Inland cave sites, apparently associated with bear hunting, have provided the oldest dates for the presence of humans on the northern Northwest Coast. In Shuká Kaa Cave on Prince of Wales Island, human remains have been directly dated to circa 10,300 cal yr BP; a potential bone artifact (possibly marking an older human presence) initially reported as associated with the human remains, has been dated to circa 12,200 cal yr BP (Dixon et al., 1997; Fedje et al., 2004).

At K1 cave, two projectile point bases were spatially associated with radiocarbon ages on bear bones dating between 12,930 and 12,570 cal yr BP (Fedje et al., 2011a). The point bases were assumed to have been deposited in the cave in wounded bears; however, only the projectile point bases rather than the complete points or point tips were recovered, and no impact damage on the skeletons has been reported, suggesting some alternative mode of deposition.

The dating of human presence at Gaadu Din 1 is based on three charcoal dates ranging from 12,680—12,550 cal yr BP and 11,610—11,270 cal yr BP associated with flakes, and a direct radiocarbon date on a bone point, 12,000—11,650 cal yr BP (Fedje et al., 2011a). Age estimates within the Gaadu Din 2 cave range between 11,750—11,320 cal yr BP on a bear bone and 13,000—12,790 cal yr BP on charcoal. Unlike the other caves yielding late Pleistocene and early Holocene ages, Gaadu Din 2 also had a stratified hearth providing a more secure association between human occupations and radiocarbon-dated material: the

upper levels of the hearth returned ages between 11,070 and 10,680 cal yr BP; middle levels separated from the upper by a layer of gravels returned ages between 12,160—11,780 cal yr BP; and a final basal age was reported as 12,570—12,420 cal yr BP.

One site on Hunter Island has returned basal dates older than 11,000 cal yr BP. Site ElTa-18, Kildidt Narrows, was tested with percussion coring initially by Cannon (2000); one core with a piece of charcoal returned a basal age between 11,610 and 12,710 cal yr BP. McLaren and others returned to the site to open a 1 × 1 meter unit, reporting four ages on charcoal from a charcoal-rich layer in organic sediments associated with a few scattered lithics: 13,740—13,410 cal yr BP, 12,820—12710 cal yr BP, and 10,770—10,610 cal yr BP (McLaren et al., 2015). The cause for such wide disparity for the Kildidt Narrows Site is difficult to assess from the published literature. McLaren et al. (2015) appear to attach each of these ages to a cultural occupation; however, the association with cultural materials or features is unclear given the limited amount of excavation (1 × 1 m and 50 × 50 cm units in total) and apparent lack of stratigraphic separation and/or association of the dates and artifacts. The potential for 'old wood' problems (e.g., driftwood) is difficult to evaluate as species identifications are not provided. Additional investigation may resolve the natural or cultural origin of the charcoal.

If Clovis progenitors inhabited the Northwest Coast during the late Glacial period, there are several areas where potential sites might be identified. Shorelines associated with the forebulge-lifted outer islands and refugia are now submerged. Recent efforts to locate underwater sites have not been successful (Mackie et al., 2013; Dixon and Monteleone, 2014). As Mackie et al. (2013) point out, the survival of intertidal sites (coastal sites that were submerged and are now becoming exposed again due to isostatic rebound) on Gwaii Haanas does indicate that earlier sites, now submerged, could have survived inundation. However, it may be worth noting that most of the 111 intertidal sites reported by Mackie et al., in 2013 are found on the mainland side of the island; the few sites on the exposed Pacific-facing coastline are protected in sheltered bays. The exposed coastal plains of the potential southeast Alaska refugia likely experienced more disturbance during their submergence; if underwater surveys are to be successful, care must be taken to sample locations that were coastal at the appropriate time, and would have experienced sufficient sedimentation during flooding to preserve site integrity. For parts of the Alexander Archipelago, the tephras produced during the repeated eruptions of Mount Edgecumbe may have helped protect earlier sites, though such locations may prove more difficult to sample. Beyond the possibility of submerged sites, caves in refugia bearing terrestrial and marine mammals' remains dating back to the later years of the LGM and the terminal Pleistocene should preserve early hunter gatherers' sites (however, we note that existing analyses indicate human occupation in these areas no earlier than 12,600 cal yr BP).

In addition, we might expect high-quality raw material sources available in refugia to be exploited early. Based on Carrara et al.'s (2007) predictions for refugium locations, the Obsidian Cove source on southern Suemez Island may have been on the edge of the exposed coastal plain and could have provided a much-needed and easily identifiable high-quality raw material source for coastal migrants, with the Aguada Cove/Port Santa Cruz source (another geochemically separate flow on the western side of same island) becoming available shortly after the outer coast began to deglaciate. In southeast Alaska, we see small amounts of Suemez Island obsidian used locally in the Alexander Archipelago after 10,700 cal yr BP, yet it is absent in sites just to the south on Haida Gwaii (Fedje et al., 2011b; Carlson,2012). That this material does not appear to have been exchanged southward in the early Holocene is

surprising, and suggests a disconnect between groups on the Northwest Coast by the time the current archaeological record in this region begins. If earlier coastal occupations exist, we may expect to find nonlocal northern lithic raw material.

To summarize, while still likely productive, the marine ecosystem along the North Pacific Coastal Route at the end of the Pleistocene may not have been as attractive as some models assume. During the ~17,000 to 14,700 BP period of coastal deglaciation, hunter-gatherers moving along the coast would have encountered marine mammals, but would have been contending with sea ice and calving glaciers. As ice receded from the outer islands, the uplifted refugia along the coast flooded swiftly as the forebulge collapsed, accompanied by as many as 19 separate eruptions from the Mount Edgecumbe volcanic field between 14,600 and 13,100 cal yr BP. The impact of these processes on mobile hunter gatherers is difficult to discern. Mackie et al. (2013) provide a reminder that the limited data points on our relative sea-level curves lend the appearance of gradual change to what was likely a more dynamic process. Between 14,000 and 10,500 cal yr BP, relative sea-level rose 5–10 cm/yr in parts of the outer coast, dramatically altering shorelines over the course of an individual's lifetime; this was likely not just a slow creep of sea-level rise, but punctuated by 'events' of sea-level change due to crustal adjustments.

If coastal-adapted hunter-gatherers had successfully crossed the ice-bound stretch of southcentral Alaska, the refugia of the Alexander Archipelago and Haida Gwaii may have provided much needed resources and tool-stone material; the geologic instability of the region may have provided the push for colonizers to continue south along the coastlines of southeast Alaska and British Columbia, and eventually into Washington, Oregon and California. A coastal migration route assumes that the current archaeological record of the Northwest Coast has not captured the earliest phase of human occupation; this assumption must continue to be tested. Underwater surveys are a natural choice, but expensive and thus far unproductive. If hunter-gatherers expanded to the islands and refugia of the coast as early as assumed (~15,000 cal yr BP), some coastal environments would have provided ready access to marine, littoral, terrestrial, and anadromous resources. These resources and the need for lithic raw material would have provoked forays farther inland into areas still above sea level today and now covered with dense temperate rain forest: difficult to reach, but more accessible to archaeologists than submerged sites.

4. Discussion

4.1. Human occupation of Beringia and Northwest North America, 14,200–11,500 cal yr BP

The archaeology of Beringia bears directly on alternate New World colonization processes. Both interior and coastal routes require different adaptive strategies. In our view, the interior route shares many similarities with periglacial conditions in Eastern Beringia, where we already have a clear pattern of human adaptive strategies in the Pleistocene. The earliest Beringian sites are in the deep interior, and a number of sites pre-date Clovis (Potter et al., 2013). Swan Point CZ4b data indicate these earliest populations were using Siberian Diuktai culture technologies, including specific microblade core and burin forms (Holmes, 2011; Hirasawa and Holmes, 2017). The bulk of the 14,000–13,000 cal yr BP data is from interior Eastern Beringian sites and a few in the interior corridor. Only three sites have been suggested to fall into this time range in the coastal route, considered broadly. Manis and Ayer Pond consist of mastodon and bison remains respectively, and questions remain as to the nature of the embedded bone fragment at Manis

(Grayson and Meltzer, 2015; Haynes and Huckell, 2016) and human agency at Ayer Pond (Haynes, 2015). The third site, Kildidt Narrows, has three non-cultural, non-overlapping dates ranging from 11,720–9480 cal yr BP (McLaren et al., 2015). The first unequivocally dated archaeological sites along the coastal route are around ~12,500 cal yr BP (Fedje et al., 2011a,b; Mackie et al., 2011), or about 1700 years after the initial Eastern Beringian occupations located deep in the interior.

The absence of any sites along southern Beringia coastal *and near-coastal* areas between 14,200 and 8000 cal yr BP is significant. From Yakutat to the Aleutians, sea level histories are characterized by a gradual sea-level regression following deglaciation, lacking the forebulge effect that complicates matters for much of southeast Alaska and northern British Columbia (Shugar et al., 2014). Even in these latter dynamic regions a 'hinge' with an apparent 15,000 years of relatively stable coastlines has been identified, though sites are not securely dated in these 'persistent places' until 11,000–10,000 cal yr BP (McLaren et al., 2015). While parts of the Pacific coast relevant to the coastal migration hypothesis are underwater, in certain locations along the Northwest Coast and across southern Beringia these late Pleistocene shorelines remain above water (Shugar et al., 2014). In addition, expected near-coastal and adjacent interior riverine occupations remain undetected.

In terms of the broadest physiographic patterns, the earliest human occupations (~14,200 cal yr BP) are along east-west trending river valleys in deep interior Eastern Beringia. Around 2000 years later (12,200 cal yr BP), there is evidence of expansion south into Pacific-draining river valleys (Kuskokwim, Susitna, Copper; Wygal and Goebel, 2012). Around 7000-5000 years after the earliest interior Eastern Beringians, the earliest southern Alaskan coastal sites appear, with technology derived from earlier interior cultures (Jordan, 1992; Dumond, 2001; Ackerman, 2007; Coutouly, 2015). These patterns are inconsistent with an initial coastal migration along the southern edge of Beringia pre-14,000 cal yr BP.

Obsidian use has been documented from the earliest occupations through the late Pleistocene and early Holocene (Reuther et al., 2011). The earliest obsidian came from interior sources (Batza Tena, Wiki Peak) and was commonly distributed along east-west trending major rivers (Yukon, Tanana, Kobuk, Noatak). This pattern continued throughout the entire period 14,000–11,500 cal yr BP, with no evidence of coastal obsidian being procured or traded along north-south Pacific coastal rivers (Susitna, Copper). These latter areas have been heavily surveyed (Dixon et al., 1985) and we do not think this pattern is explained by poor sampling.

We have previously suggested an alternate model for the earliest colonization evident along the coastal route (Potter et al., 2013). Instead of a remnant population of earlier people retreating from sea level advance (Maschner, 2016:325) for which we have no direct evidence, these early sites may reflect populations from interior regions expanding to new areas during the onset of the Younger Dryas, which appears to have adversely affected interior populations, given evidence for increasing diet breadth during the Younger Dryas (Potter et al., 2013). During the Younger Dryas, coterminous with slightly decreasing population proxies in the interior, there is not only expansion to adjacent coastal regions to the south but also the earliest known sites in southwest Alaska (Kuskokwim watershed), and multiple occupations in the Brooks Range (Northern Alaska), and renewed occupation in the interior corridor (7 sites dated between 12,800–11,700 cal yr BP, Potter et al., 2013).

4.2. Evaluation of colonization routes

The data and analyses above allow a re-evaluation of the two

proposed routes for colonization of Clovis progenitors south of the ice sheets. Based on geological data reviewed above, a corridor ~300-150 km wide opened between the CIS and LIS by at least 15 kya, expanding to at least 300 km wide (at the narrowest point near Charlie Lake) at 14 kya. Sand dune stabilization dates indicate Dyke's models under-estimated the timing of deglaciation in the central corridor region. By 12,600 cal yr BP, the date argued by Pedersen et al. (2016) to reflect the earliest biological viability of the IFC, the corridor was several hundred km wide (Munyikawa et al., 2017: Fig. 6). The extent and timing of drainage of proglacial lakes within the corridor are uncertain at present, but the data presented above indicate that the interior route was viable with plant and animal resources at least by ~13,560 cal yr BP, well prior to widespread Clovis occupations south of the Ice Sheets. A freshly deglaciated landscape with stagnant ice, katabatic winds, shifting drainages, large bodies of seasonal water, and perhaps surges of meltwater has been construed as uninhabitable (Mandryk et al., 2001). However, early Beringians would have been uniquely positioned to deal with these rigors, as they were already adapted to periglacial conditions in central Alaska and Yukon Territory.

We consider the Pacific coast, particularly west of Alexander Archipelago, to still be a plausible migration route, either in early or later periods, but some issues raised here should be considered. While refugia have been documented in the southern areas, south of the Alexander Archipelago (see above), there are few data for the 2000 km stretch between Yakutat and the Aleutians. Only one (unpublished) record exists for the entire Gulf of Alaska, and that suggests marine mammal productivity after 15,500 cal yr BP (Crossen et al., 2010), but it is difficult to extrapolate beyond the local area. Besides shorefast ice, potential colonists would have to deal with seasonal sea ice that extended far south of modern distributions, as well as icebergs. This ice was likely present 8—9 months out of the year, adding complications to estimates of biological productivity. Thick perennial ice would not provide habitats throughout the year for seals and other marine mammals that were important for later peoples in the region. Hunting and navigating on drift ice requires complex hunting and transportation technologies, including composite toggling harpoon systems, drag-float systems, umiaks, kayaks, and dog sleds (see discussion in Yesner et al., 1980). The Late Upper Paleolithic Siberian and earliest Beringian cultural complexes do not contain these technologies. We argue the risk of such a significant adaptive shift may have been too great given pre-existing Siberian adaptations for terrestrial subsistence and land use. The deaths of three young individuals at Upward Sun River at ~11,500 cal yr BP during the summer, the season with high resource abundance and diversity and least expected resource stress, suggests that the earliest Beringians faced more resource stress than usually assumed (Potter et al., 2014).

We raise other points that appear relevant to the coastal route hypothesis. A number of late Pleistocene coastal areas have been uplifted through isostatic rebound and are currently accessible. After decades of survey, no securely dated pre-12,500 cal yr BP site has been located along the coastal route, or along salmon rivers leading to the coast. Beyond early Northwest Coast material, every other known cultural tradition in the region with evidence for coastal or maritime adaptations dates to the middle Holocene and later, and all have associated inland occupations, including Choris, Norton, Ipiutak, Kachemak, and Thule. Surovell's (2003) argument based on optimal foraging modeling remains unrefuted. The presence of stabilized shorelines but no evidence for coastal occupations and maritime adaptations for thousands of years in the early Holocene is inconsistent with very early maritime adaptation. The only early coastal human remains, at Shuka-Kaa, dating to 10,300 cal yr BP (nearly 4000 years after the earliest Beringians), have a marine isotope signature (Dixon, 2008), though isotope-

based diet reconstructions for the region (Schwarcz et al., 2014) suggest this may be due to salmon exploitation rather than marine mammal hunting (see also Moss and Cannon, 2011). The widespread Northeast Asian Diuktai culture, likely directly ancestral to the earliest Beringians, exhibits no coastal adaptations in terms of technology, economy, or settlement systems. There is no evidence for any coastal or maritime economies in the Kuriles, Kamchatka, Chukotka, or the north coast of the Sea of Okhotsk until the middle Holocene (Fitzhugh, 2016).

Conversely, the data suggest that the interior route was available and biologically viable prior to the first widespread cultural manifestation south of the ice sheets, Clovis and related complexes. The Siberian and Beringian data demonstrate interior-focused hunter-gatherers expanding through interior river valleys during the Late Glacial. The undated fluted point distributions in Alberta and interior British Columbia show close conformity to glacial ice margins at 13,300, not 12,500 cal yr BP (Ives et al., 2013) suggesting an early age for these points (see Dawe and Kornfeld, this volume).

5. Conclusions

In sum, our review of IFC geological and paleoecological data indicates a *minimum* age of opening of the bottleneck region by 14,900 cal yr BP, based on landscapes, such as dunes, that formed after the opening, with deglaciation initiated to the north and south of the bottleneck by ~19,000 cal yr BP. This puts a minimum limiting age on human migration through the IFC of 14,900 cal yr BP, assuming the migrants were constrained by the presence of glaciers and glacial lakes (Freeman, 2016). A *minimum* age of the biological viability of the IFC is more difficult to estimate, but data suggest the presence of vegetation in the bottleneck by ~13,555 cal yr BP, and perhaps by 14,900 cal yr BP, based on Taiga voles at Bear Flat, Alberta (Hebda et al., 2008). Bison were present in the bottleneck by at least 13,100 cal yr BP (Shapiro et al., 2004; Heintzman et al., 2016). Finally, eDNA and palynological datasets indicate biotic viability by at least 12,600 cal yr BP at Charlie Lake and Spring Lake (Pedersen et al., 2016). Collectively, these data indicate that the IFC opening and viability predates Clovis, and we agree with Ives et al. (2013) and Freeman (2016) that we cannot reject the hypothesis of migration(s) of Clovis progenitors through the IFC. If the minimum dates of 14,900 cal yr BP are representative for this IFC bottleneck, then there is even potential for some pre-Clovis progenitors (e.g., Paisley 5 Mile Point Caves, Page-Ladson, Schaefer, Manis, and possibly Monte Verde) to have traversed the IFC.

Previous coastal migration models largely rely on data from the southern end of the coastal area, i.e., Haida Gwaii (Erlandson et al., 2015; McLaren et al., 2015). Data from coastal areas to the north (e.g., Gulf of Alaska, Kodiak, Alaska Peninsula) are more ambiguous. Our critical evaluation of paleoecological and archaeological data for the entire ~3500 km stretch of coast between the Aleutian Islands and Vancouver Island suggests issues that should be addressed in coastal migration models. Currently, data for coastal deglaciation are uneven: glacial recession may have begun as early as 19,000 cal yr BP for parts of southcentral Alaska and the Aleutian chain and the outer islands of British Columbia; however, deglacial sequencesremain poorly dated for other sections of southcentral and southeast Alaska (Shugar et al., 2014, and references above). Evidence for revegetation or refugia is equally sporadic, though with dates as early as 18,000—17,000 cal yr BP in some locations (e.g., Haida Gwaii). There is evidence for multiple refugia in the Haida Gwaii/Hecate Strait area (Lacourse et al., 2005) and southern outer Alexander Archipelago (Carrara et al., 2007). However, the extent of these habitable zones is unclear, and there is currently sparse direct evidence for refugia farther north and northwest

(Crossen et al., 2010; Misarti et al., 2012).

We provide details on some of the expected cultural adaptations necessary for high latitude coastal colonization during the late Pleistocene and their absence in extant Beringian sites. Current data indicate that the earliest securely dated coastal occupations post-date the earliest Beringian (interior) sites by 1700 years, and are limited to the southern part of the coastal corridor. The earliest sites for much of the rest of the coastal route date between 7000 and 5000 years after the earliest interior occupations. While sea level rise following deglaciation will have inundated some late Pleistocene sites, other areas which should preserve evidence of an early coastal colonization (e.g., uplifted paleoshorelines, along salmon rivers, caves with pre-Clovis-age fauna) have thus far not yielded evidence of early human occupation. Our analysis of obsidian distributions and previous typological analyses (Dumond, 2001; Coutouly, 2015) suggest an early colonization of interior Eastern Beringia and a later expansion to Alaskan coasts.

We do not posit here that either route is *demonstrated* to have been used or unused by early Paleoindian ancestors. Both may have been used at different times and by one or more populations moving north or south. Models of cultural adaptations and migration routes remain constrained by absent and/or ambiguous data. However, a preponderance of the current evidence suggests that we cannot reject the interior route. More work is needed in both coastal and interior route areas, grounded in secure chronological controls of deglaciation, deposition, revegetation and habitat development. More phylogenetic analyses of other species north and south of the IFC, both large and small game, would add valuable data to this question. Relict late Pleistocene coastal areas raised through isostatic rebound should be intensively surveyed, along with continued survey along salmon-bearing rivers. Continued geoarchaeological analyses in both IFC and coastal areas are critical to resolve these ambiguities.

Acknowledgments

References

Achilli, A., Perego, U.A., Lancioni, H., Olivieri, A., Gandini, F., Hooshiar Kashani, B., Battaglia, V., Grugni, V., Angerhofer, N., Rogers, M.P., Herrera, R.J., Woodward, S.R., Labuda, D., Smith, D.G., Cybulski, J.S., Semino, O., Malhi, R.S., Torroni, A., 2013. Reconciling migration models to the Americas with the variation of North American native mitogenomes. Proc. Natl. Acad. Sci. U. S. A. 110, 14308–14313.

Ackerman, R.E., 2007. The microblade complexes of Alaska and the Yukon: early interior and coastal adaptations. In: Kuzmin, Y.V., Keates, S.G., Chen, S. (Eds.), Origin and Spread of Microblade Technology in Northern Asia and North America. Simon Fraser University Archaeology Press, Burnaby, pp. 147–170.

Addison, J.A., Beget, J.E., Ager, T.A., Finney, B.P., 2010. Marine tephrochronology of the Mt. Edgecumbe volcanic field, Southeast Alaska, USA. Quat. Res. 73, 277–292.

Addison, Jason A., Finney, Bruce P., Dean, Walter E., Davies, Maureen H., Mix, Alan C., Stoner, Joseph S., Jaeger, John M., 2012. Productivity and sedimentary d15N variability for the last 17,000 years along the northern Gulf of Alaska continental slope. Paleoceanography 27 (PA1206), 1–17.

Adovasio, J.M., Pedler, D.R., Graf, K.E., Ketron, C.V., Waters, M.R., 2013. The ones that still won't go away: more biased thoughts on the pre-Clovis peopling of the New World. In: Paleoamerican Odyssey, pp. 511–520.

Ager, T.A., 2000. Postglacial vegetation history of the Kachemak Bay area, Cook inlet. In: Geologic Studies in Alaska by the US Geological Survey during, p. 147.

Ager, T.A., Rosenbaum, J.G., 2009. Late glacial-holocene pollen-based vegetation history from pass lake, Prince of Wales Island, Southeastern Alaska. In: Haeussler, P.J., Galloway, J.P. (Eds.), Studies by the U.S. Geological Survey in Alaska, 2007: U.S. Geological Survey Professional Paper 1760-G.

Ager, T.A., Carrara, P.E., Smith, J.L., Anne, V., Johnson, J., 2010. Postglacial vegetation history of Mitkof Island, Alexander Archipelago, southeastern Alaska. Quat. Res. 73, 259–268.

Barron, J.A., Bukry, D., Dean, W.E., Addison, J.A., Finney, B., 2009. Paleoceanography of the Gulf of Alaska during the past 15,000 years: results from diatoms, silicoflagellates, and geochemistry. Mar. Micropaleontol. 72, 176–195.

Barton, C.M., Schmich, S., James, S.R., 2004. The ecology of human colonization in pristine landscapes. In: The Settlement of the American Continents: a Multidisciplinary Approach to Human Biogeography, p. 138.

Bever, M.R., 2001. Stone tool technology and the mesa complex: developing a framework of alaskan paleoindian prehistory. Arct. Anthropol. 38, 98–118.

Borden, C., 1975. Origins and development of early Northwest Coast culture to about 3000 B.C.. In: National Museum of Man Mercury Series, Archaeological Survey of Canada.

Bradley, B.A., Collins, M.B., Hemmings, A., 2010. Clovis technology. International Monographs in Prehistory.

Bryan, A., 2000. The Lindoe Site, Southeastern Alberta. Non-permit. In: Archaeological Survey of Alberta, Edmonton.

Bunbury, J., Gajewski, K., 2009/2. Postglacial climates inferred from a lake at treeline, southwest Yukon Territory, Canada. Quat. Sci. Rev. 28, 354–369.

Burns, J.A., 1996. Vertebrate paleontology and the alleged ice-free corridor: the meat of the matter. Quat. Int. 32, 107–112.

Burns, J.A., 2010. Mammalian faunal dynamics in late Pleistocene Alberta, Canada. Quat. Int. 217, 37–42.

Buvit, I., Terry, K., 2016. Outside Beringia: why the Northeast Asian Upper Paleolithic record does not support a long standstill model. PaleoAmerica 2, 4.

Caissie, B.E., Brigham-Grette, J., Lawrence, K.T., Herbert, T.D., Cook, M.S., 2010. Last Glacial Maximum to Holocene sea surface conditions at Umnak Plateau, Bering Sea, as inferred from diatom, alkenone, and stable isotope records. Paleoceanography 25, PA1206.

Cannon, A., 2000. Settlement and sea-levels on the central coast of British Columbia: evidence from shell midden cores. Am. Antiq. 65, 67–77.

Carlson, R.J., 2012. A Predictive Model for Early Holocene Archaeological Sites in Southeast Alaska Based on Elevated Palaeobeaches (Ph.D.). University of Cambridge.

Carlson, R.J., Baichtal, J.F., 2015. A predictive model for locating early holocene archaeological sites based on raised Shell-bearing Strata in southeast Alaska, USA. Geoarchaeology 30, 120–138.

Carlson, R.L., 1994. Trade and Exchange in Prehistoric British Columbia, in: Prehistoric Exchange Systems in North America, Interdisciplinary Contributions to Archaeology. Springer US, pp. 307–361.

Carrara, P.E., Ager, T.A., Baichtal, J.F., 2007. Possible refugia in the Alexander Archipelago of southeastern Alaska during the late Wisconsin glaciation. Can. J. Earth Sci. 44, 229–244.

Catto, Norman, Liverman, David G.E., Bobrowsky, Peter T., Rutter, Nat, 1996. Laurentide, cordilleran, and montane glaciation in the western Peace River — Grande Prairie region, Alberta and British Columbia. Canada. Quat. Int 32, 21–32.

Chapin, F.S., Walker, L.R., Fastie, C.L., Sharman, L.C., 1994. Mechanisms of primary succession following deglaciation at Glaier Bay, Alaska. Ecol. Monogr. 64 (2), 149–175.

Clague, J.J., Mathewes, R.W., Ager, T.A., 2004. Environments of Northwestern North America before the Last Glacial Maximum. In: Entering America: Northeast Asia and Beringia.

Collins, M.B., 1999. Clovis Blade Technology: a Comparative Study of the Keven Davis Cache.

Collins, M.B., Stanford, D.J., Lowery, D.L., Bradley, B.A., 2013. North America before Clovis: variance in temporal/spatial cultural patterns, 27,000–13,000 cal yr BP. In: Paleoamerican Odyssey, pp. 521–539.

Coutouly, Y.A.G., 2015. Anangula — a major pressure-microblade site in the Aleutians, Alaska. Reevaluating its lithic component. Arct. Anthropol. 52, 23–59.

Crossen, K.J., Pasch, A., Yesner, D., 2010. Discovery of potential marine resources to support early human coastal migrants in the Gulf of Alaska. In: 2010 GSA Annual Meeting.

Davies, M.H., Mix, A.C., Stoner, J.S., Addison, J.A., Jaeger, J., Finney, B., Wiest, J., 2011. The deglacial transition on the southeastern Alaska Margin: meltwater input, sea level rise, marine productivity, and sedimentary anoxia. Paleoceanography 26, PA2223.

Davis, R., Knecht, R., Rogers, J., 2016. First maritime cultures of the Aleutians. In: Friesen and, Max (Ed.), The Oxford Handbook of the Prehistoric Arctic. Oxford University Press, pp. 279–302.

Dickinson, W.R., 2011. Geological perspectives on the Monte Verde archeological site in Chile and pre-Clovis coastal migration in the Americas. Quat. Res. 76, 201–210.

Dikov, N., 2003. Archaeological sites of Kamchatka, Chukotka, and the upper Kolyma. US Dept. of the Interior, National Park Service, Shared Beringian Heritage Program.

Dillehay, T.D., 1997. Monte Verde: a Late Pleistocene Settlement in Childe, Vol. II, the Archaeological Context and Interpretation. Smithsonian, Washington, D.C.

Dincauze, D.F., 1984. An archaeological evaluation of the case for pre-Clovis occupations. Adv. world Archaeol. 3, 275—323.

Dixon, E.J., 2001. Human colonization of the Americas: timing, technology and process. Quat. Sci. Rev. 20, 277—299.

Dixon, E.J., 2011. Late Pleistocene colonization of north America from northeast Asia: new insights from large-scale paleogeographic reconstructions. Quat. Int. 285, 57—67.

Dixon, E.J., 2008. Bifaces from on Your Knees cave, southeast Alaska. In: Carlson, R.L., Magne, M.P.R. (Eds.), Projectile Point Sequences in Northwestern North America. Archaeology Press, Burnaby, B. C, pp. 11—18.

Dixon, E.J., 2013. Late Pleistocene colonization of north America from northeast Asia: new insights from large-scale paleogeographic reconstructions. Quat. Int. 285, 57—67.

Dixon, E.J., Heaton, T.H., Fifield, T.E., Hamilton, T.D., Putnam, D.E., Frederick, G., 1997. Late Quaternary regional geoarchaeology of Southeast Alaska karst: a progress report. Geoarchaeology.

Dixon, E.J., Monteleone, K., 2014. Gateway to the Americas: underwater archeological survey in Beringia and the north pacific. In: Prehistoric Archaeology on the Continental Shelf. Springer, New York, pp. 95—114.

Dixon Jr., E.J., Smith, G.S., Andrefsky, W., Saleeby, B.M., Utermohle, C.J., 1985. Susitna Hydroelectric Project cultural resource investigations: 1979—1985. In: Report Prepared for the Alaska Power Authority by the University of Alaska Museum, Fairbanks. Available from University of Alaska Fairbanks, Rasmuson Library.

Driver, J.C., 1998. Human adaptation at the Pleistocene/Holocene boundary in western Canada. Quat. Int. 49—50, 141—150.

Driver, Jonathan C., Handly, Martin, Fladmark, Knut R., Nelson, D. Erie, Sullivan, Gregg M., Preston, Randall, 1996. Stratigraphy, radiocarbon dating and culture history of Charlie Lake Cave, British Columbia. Arctic 49 (3), 265—277.

Dumond, D.E., 2001. Towards a (Yet) newer view of the (Pre)history of the Aleutians. In: Dumond, D.E. (Ed.), Archaeology in the Aleut Zone of Alaska, Some Recent Research, University of Oregon Anthropological Papers, 58. Eugene, Oregon, pp. 289—309.

Dyke, A.S., 2004. An outline of North American deglaciation with emphasis on central and northern Canada. In: Ehlers, J., Gibbard, P.L. (Eds.), Developments in Quaternary Sciences, Vol 2b. Elsevier, Amsterdam, pp. 373—424.

Dyke, A.S., 2005. Late Quaternary vegetation history of northern North America based on pollen, macrofossil, and faunal remains. Géogr. Phys. Quat. 59, 211—262.

Dyke, A.S., Moore, A., Robertson, L., 2003. Deglaciation of North America. In: Geological Survey of Canada, Open File 1574, 2 Sheets. Ottawa, Ontario, Canada.

Dyke, A.S., Andrews, J.T., Clark, P.U., England, J.H., Miller, G.H., Shaw, J., Veillette, J.J., 2001. Radiocarbon dates pertinent to defining the last glacial maximum for the Laurentide and innuitian ice sheets. In: Geological Survey of Canada, Open File 4120. Ottawa, Ontario, Canada.

Easton, N.A., 1996. Mal de mer above terra incognita, or, "What ails the coastal migration theory?". Arct. Anthropol. 29, 28—42.

Eren, M.I., 2013. The technology of Stone Age colonization: an empirical, regional-scale examination of Clovis unifacial stone tool reduction, allometry, and edge angle from the North American Lower Great Lakes region. J. Archaeol. Sci. 40, 2101—2112.

Eren, M.I., Buchanan, B., 2016. Clovis technology. In: eLS: Citable Reviews in Life Science.

Eren, M.I., Buchanan, B., O'Brien, M.J., 2015. Social learning and technological evolution during the Clovis colonization of the New World. J. Hum. Evol. 80, 159—170.

Erlandson, J.M., 2013. After clovis-first collapsed: reimagining the peopling of the Americas. In: Graf, K., Waters, M.R., Ketron, C.V. (Eds.), Paleoamerican Odyssey. Texas A&M University Press, College Station, pp. 127—132.

Erlandson, J.M., Braje, T.J., Gill, K.M., Graham, M.H., 2015. Ecology of the kelp highway: did marine resources facilitate human dispersal from Northeast Asia to the Americas? J. Isl. Coast. Archaeol. 10, 392—411.

Erlandson, J.M., Graham, M.H., Bourque, B.J., Corbett, D., Estes, J.A., Steneck, R.S., 2007. The kelp highway hypothesis: marine ecology, the coastal migration theory, and the peopling of the Americas. J. Isl. Coast. Archaeol. 2, 161—174.

Fedje, D., Mackie, Q., Lacourse, T., McLaren, D., 2011a. Younger Dryas environments and archaeology on the Northwest Coast of North America. Quat. Int. 242, 452—462.

Fedje, D., Mackie, Q., Smith, N., Mclaren, D., 2011b. Function, visibility, and interpretation of archaeological assemblages at the pleistocene/holocene transition in Haida Gwaii. In: Goebel, T., Buvit, I. (Eds.), From the Yenisei to the Yukon : Interpreting Lithic Assemblage Variability in Late Pleistocene/early Holocene Beringia. Texas A&M University Press.

Fedje, D.W., Mackie, Q., Dixon, E.J., Heaton, T.H., 2004. Late Wisconsin environments and archaeological visibility on the northern Northwest Coast. In: Entering America: Northeast Asia and Beringia before the Last Glacial Maximum, p. 97.

Fiedel, S.J., 2013. The Search for pre-clovis in eastern north America: a critical evaluation of the evidence. In: Gingerich, J.A.M. (Ed.), The Eastern Fluted Point Tradition. University of Utah Press, Salt Lake City, pp. 333—354.

Fiedel, S.J., 2014. The clovis-era radiocarbon plateau. In: Smallwood, A.M., Jennings, T.A. (Eds.), Clovis: on the Edge of a New Understanding. Texas A&M University Press, College Station.

Fitzhugh, B., 2016. The origins and development of arctic maritime adaptations in the Subarctic and arctic pacific. In: Friesen, Max (Ed.), The Oxford Handbook of the Prehistoric Arctic. Oxford University Press, pp. 253—278.

Fladmark, K.R., 1979. Routes: alternate migration corridors for early man in north America. Am. Antiq. 44, 55—69.

Fladmark, K.R., Driver, J.C., Alexander, D., 1988. The paleoindian component at Charlie Lake cave (HbRf 39), British Columbia. Am. Antiq. 53, 371—384.

Freeman, A., 2016. Why the ice-free corridor is still relevant to the peopling of the New World. In: Kornfeld, M., Huckell, B.B. (Eds.), Stones, Bones and Profiles : Exploring Archaeological Context, Early American Hunter-gatherers, and bison. University Press of Colorado, Boulder, pp. 51—74.

Gelvin-Reymiller, C., Potter, B.A., 2009. Site Location Model and Survey Strategy for Cultural Resources in the White Mountain National Recreation Area and Steese National Conservation Areas. Prepared for BLM, by the Archaeology GIS Laboratory, University of Alaska Fairbanks.

Goebel, T., 2002. The "microblade adaptation" and recolonization of Siberia during the late upper Pleistocene. In: Archeological Papers of the American Anthropological Association, vol. 12, pp. 117—131.

Goebel, T., Potter, B., 2016. First traces. In: The Oxford Handbook of the Prehistoric. Oxford University Press, pp. 223—252.

Goebel, T., Potter, B., 2016. First traces. In: The Oxford Handbook of the Prehistoric Arctic. Oxford University Press, p. 223.

Goebel, T.E., Powers, W.R., Bigelow, N.H., 1991. The Nenana complex of Alaska and Clovis origins. In: Bonnichsen and, R. (Ed.), Clovis Origins and Adaptations. Center for the Study of the First Americans. Oregon State University, Corvallis, pp. 49—79.

Goebel, T.E., Smith, H.L., DPietro, L., Waters, M.R., Hockett, B., Graf, K.E., Gal, R., Slobodin, S.B., Speakman, R.J., Driese, S.G., Rhode, D., 2013. Serpentine Host Springs, Alaska: results of excavations and implications for the age and significance of northern fluted points. J. Archaeol. Sci. 40, 4222—4233.

Golden, J.L., Bain, J.F., 2000. Phylogeographic patterns and high levels of chloroplast DNA diversity in four Packera (asteraceae) species in southwestern Alberta. Evolution 54, 1566—1579.

Gómez-Coutouly, Y.A., 2012. Pressure microblade industries in pleistocene-holocene interior Alaska: current data and discussions. In: The Emergence of Pressure Blade Making. Springer US, pp. 347—374.

Graham, M.H., Kinlan, B.P., Grosberg, R.K., 2010. Post-glacial redistribution and shifts in productivity of giant kelp forests. Proc. Biol. Sci. 277, 399—406.

Grayson, D.K., Meltzer, D.J., 2002. Clovis hunting and large mammal extinction: a critical review of the evidence. J. World Prehist. 16, 313—359.

Grayson, D.K., Meltzer, D.J., 2015. Revisiting paleoindian exploitation of extinct North American mammals. J. Archaeol. Sci. 56, 177—193.

Gustafson, C.E., Gilbow, D.W., Daugherty, R.D., 1979. The Manis mastodon site: early man on the olympic Peninsula. Can. J. Archaeol./J. Can. d'Archéol. 157—164.

Halffman, C.M., Potter, B.A., McKinney, H.J., Finney, B.P., Rodrigues, A.T., Yang, D.Y., Kemp, B.M., 2015. Early human use of anadromous salmon in North America at 11,500 y ago. Proc. Natl. Acad. Sci. U. S. A. 112, 12344—12348.

Hamilton, M.J., Buchanan, B., 2007. Spatial gradients in Clovis-age radiocarbon dates across North America suggest rapid colonization from the north. Proc. Natl. Acad. Sci. U. S. A. 104, 15625—15630.

Hansen, B.C.S., Engstrom, D.R., 1996. Vegetation history of pleasant island, Southeastern Alaska, since 13,000 yr B.P. Quat. Res. 46, 161—175.

Hartman, G.M.D., Clague, J.J., 2008. Quaternary stratigraphy and glacial history of the Peace River valley, northeast British Columbia. Can. J. Earth Sci. 45, 549—564.

Hastings, K., 2005. Long-term Persistence of Isolated Fish Populations in the Alexander Archipelago. The University of Montana.

Haynes, V.C., Huckell, B.B., 2016. The Manis mastodon: an alternative interpretation. PaleoAmerica 2, 189—191.

Haynes, C.V., 2006. Clovis progenitors: from Swan Point, Alaska to Anzick Site, Montana, in Less than a Decade. Manuscript in author's possession.

Haynes, G., 2015. The millennium before Clovis. PaleoAmerica 1, 134—162.

Haynes, Gary G., Anderson, David G., Reid Ferring, C., Fiedel, Stuart J., Grayson, Donald K., Vance Haynes Jr., C., Holliday, Vance T., Huckell, Bruce B., Kornfeld, Marcel, Meltzer, David J., Morrow, Juliet E., Surovell, Todd A., Waguespack, Nicole M., Wigand, Peter, Yohe, Rober M., 2007. Comment on "redefining the age of Clovis: implications for the peopling of the Americas." Science 317, 320.

Heaton, T., Grady, G., 2003. The late Wisconsin vertebrate history of Prince of Wales Island, southeast Alaska. In: Ice Age Cave Faunas of North America.

Hebda, R.J., Burns, J.A., Geertsema, M., 2008. AMS-dated late Pleistocene taiga vole (Rodentia: Microtus xanthognathus) from northeast British Columbia, Canada: a cautionary lesson in chronology. Can. J. Earth Sci. 45, 611—618.

Heintzman, P.D., Froese, D., Ives, J.W., Soares, A.E.R., Zazula, G.D., Letts, B., Andrews, T.D., Driver, J.C., Hall, E., Hare, P.G., Jass, C.N., MacKay, G., Southon, J.R., Stiller, M., Woywitka, R., Suchard, M.A., Shapiro, B., 2016. Bison phylogeography constrains dispersal and viability of the Ice Free Corridor in western Canada. Proc. Natl. Acad. Sci. U. S. A. 113, 8057—8063.

Hetherington, R., Barrie, J.V., Reid, R.G.B., MacLeod, R., Smith, D.J., 2004. Paleogeography, glacially induced crustal displacement, and Late Quaternary coastlines on the continental shelf of British Columbia, Canada. Quat. Sci. Rev. 23, 295—318.

Hey, J., 2005. On the number of New World founders: a population genetic portrait of the peopling of the Americas. PLoS Biol. 3, e193.

Hickin, A.S., Lian, O.B., Levson, V.M., Cui, Y., 2015. Pattern and chronology of glacial Lake Peace shorelines and implications for isostasy and ice-sheet configuration in northeastern British Columbia, Canada. Boreas 44, 288—304.

Hirasawa, Y., Holmes, C.E., 2017. The relationship between microblade morphology and production technology in Alaska from the perspective of the Swan Point site. Quat. Int. 442 (Part B), 104—117.

Hoffecker, J.F., Powers, W.R., Goebel, T., 1993. The colonization of Beringia and the peopling of the new World. Science 259, 46—53.

Hoffecker, J.F., Elias, S.A., O'Rourke, D.H., Scott, G.R., Bigelow, N.H., 2016. Beringia and the global dispersal of modern humans. Evol. Anthropol. 25, 64—78.

Holmes, C.E., 2001. Tanana River Valley archaeology, circa 14,000-9000 BP. Arct. Anthropol. 38, 154—170.

Holmes, C.E., 2008. The Taiga period: holocene archaeology of the northern boreal forest, Alaska. Alaska J. Anthropol. 6, 69—81.

Holmes, C.E., 2011. The Beringian and transitional periods in Alaska: technology of the east Beringian tradition as viewed from swan point. In: Goebel, Ted (Ed.), From the Yenisei to the Yukon: Interpreting Lithic Assemblage Variability in Late Pleistocene/Early Holocene Beringia. Texas A&M University Press, College Station, pp. 179—191.

Hope, A.G., Waltari, E., Malaney, J.L., Payer, D.C., Cook, J.A., Talbot, S.L., 2015. Arctic biodiversity: increasing richness accompanies shrinking refugia for a cold-associated tundra fauna. Ecosphere 6, 1—67.

Ives, J.W., Froese, D., Supernant, K., Yanicki, G., Graf, K.E., Ketron, C.V., Waters, M.R., 2013. Vectors, vestiges and Valhallas—rethinking the corridor. In: Paleoamerican Odyssey, pp. 149—169.

Jackson Jr., Lionel E., Phillips, Fred M., Shimamura, Kazuharu, Little, Edward C., 1997. Cosmogenic 36Cl dating of the Foothills erratics train, Alberta, Canada. Geology 25 (3), 195—198.

Jackson Jr., L.E., Leboe, E.R., Little, E.C., Holme, P.J., Hicock, S.R., Shimamura, K., Nelson, F.E.N., 2008. Quaternary stratigraphy and geology of the Foothills, southwestern Alberta. Geol. Surv. Can. Bull. 583. CD-ROM, Ottawa.

Jackson, L.E., Phillips, F.M., Little, E.C., 1999a. Cosmogenic 36Cl dating of the maximum limit of the Laurentide ice sheet in southwestern Alberta. Can. J. Earth Sci. 36, 1347—1356.

Jackson, L.E., Phillips, F.M., Shimamura, K., Little, E.C., 1999b. Cosmogenic 36Cl dating of the Foothills erratics train, Alberta, Canada. Can. J. Earth Sci. 25, 195—198.

Jones, M.C., Peteet, D.M., Kurdyla, D., Guilderson, T., 2009. Climate and vegetation history from a 14,000-year peatland record, Kenai Peninsula, Alaska. Quat. Res. 72, 207—217.

Jordan, R.H., 1992. A maritime paleoarctic assemblage from crag point, Kodiak island, Alaska. In: Anthropological Papers of the University of Alaska, 24(1—2), pp. 127—140.

Jull, A.J.T., Geertsema, M., 2006. Over 16,000 years of fire frequency determined from AMS radiocarbon dating of soil charcoal in an alluvial fan at Bear Flat, northeastern British Columbia. Radiocarbon 48, 435.

Kashani, B.H., Perego, U.A., Olivieri, A., Angerhofer, N., Gandini, F., Carossa, V., Lancioni, H., Semino, O., Woodward, S.R., Achilli, A., Others, 2012. Mitochondrial haplogroup C4c: a rare lineage entering America through the ice-free corridor? Am. J. Phys. Anthropol. 147, 35—39.

Kenady, S.M., Wilson, M.C., Schalk, R.F., Mierendorf, R.R., 2011. Late Pleistocene butchered Bison antiquus from ayer Pond, orcas island, pacific northwest: age confirmation and taphonomy. Quat. Int. 233, 130—141.

Kennedy, K.E., Froese, D.G., Zazula, G.D., Lauriol, B., 2010/5. Last Glacial Maximum age for the northwest Laurentide maximum from the Eagle River spillway and delta complex, northern Yukon. Quat. Sci. Rev. 29, 1288—1300.

Koppel, T., 2016. Stepping into the past: the Discovery of 13,000-year-old footprints on a remote island in western Canada indicate that people were living on the Pacific Coast during the Clovis period. Am. Archaeol. Fall 22—29.

Lacourse, T., Delepine, J.M., Hoffman, E.H., Mathewes, R.W., 2012. A 14,000 year vegetation history of a hypermaritime island on the outer Pacific coast of Canada based on fossil pollen, spores and conifer stomata. Quat. Res. 78, 572—582.

Lacourse, T., Mathewes, R.W., Fedje, D.W., 2005. Late-glacial vegetation dynamics of the queen charlotte islands and adjacent continental shelf, British Columbia, Canada. Palaeogeogr. Palaeoclimatol. Palaeoecol. 226, 36—57.

Lanoë, F.B., Holmes, C.E., 2016. Animals as raw material in Beringia: insights from the site of swan point CZ4B. Alsk. Am. Antiq. 81, 682—696.

Llamas, B., Fehren-Schmitz, L., Valverde, G., Soubrier, J., Mallick, S., Rohland, N., Nordenfelt, S., Valdiosera, C., Richards, S.M., Rohrlach, A., Romero, M.I.B., Espinoza, I.F., Cagigao, E.T., Jiménez, L.W., Makowski, K., Reyna, I.S.L., Lory, J.M., Torrez, J.A.B., Rivera, M.A., Burger, R.L., Ceruti, M.C., Reinhard, J., Spencer Wells, R., Politis, G., Santoro, C.M., Standen, V.G., Smith, C., Reich, D., Ho, S.Y.W., Cooper, A., Haak, W., 2016. Ancient mitochondrial DNA provides high-resolution time scale of the peopling of the Americas. Sci. Adv. 2, e1501385.

Loehr, J., Worley, K., Grapputo, A., Carey, J., Veitch, A., Coltman, D.W., 2006. Evidence for cryptic glacial refugia from North American mountain sheep mitochondrial DNA. J. Evol. Biol. 19, 419—430.

Lothrop, J.C., Lowery, D.L., Spiess, A.E., Ellis, C.J., 2016. Early human settlement of northeastern north America. PaleoAmerica 2, 192—251.

Mackie, Q., Fedje, D., McLaren, D., Smith, N., McKechnie, I., 2011. Early environments and archaeology of coastal British Columbia. In: Trekking the Shore, Interdisciplinary Contributions to Archaeology. Springer, New York, pp. 51—103.

Mackie, Q., Davis, L., Fedje, D., McLaren, D., 2013. Locating Pleistocene-age submerged archaeological sites on the Northwest Coast: current status of research and future directions. In: Paleoamerican.

Madsen, D.B., 2015. A framework for the initial occupation of the Americas. PaleoAmerica 1.3, 217—250.

Maher, L.J., Mickelson, D.M., 1996. Palynological and radiocarbon evidence for deglaciation events in the Green Bay Lobe, Wisconsin. Quat. Res. 46 (3), 251—259.

Mandryk, C.A.S., 1996. Late wisconsinan deglaciation of Alberta: processes and paleogeography. Quat. Int. 32, 79—85.

Mandryk, C.A.S., Josenhans, H., Fedje, D.W., Mathewes, R.W., 2001. Late Quaternary paleoenvironments of Northwestern North America: implications for inland versus coastal migration routes. Quat. Sci. Rev. 20, 301—314.

Mandryk, Carol A.S., 2004. Invented traditions and the ultimate American origin myth: In the beginning... there was an ice-free corridor. In: Michael Barton, C., Clark, Geoffrey A., Yesner, David R., Pearson, Georges A. (Eds.), The settlement of the American continents: a multidisciplinary approach to human biogeography. The University of Arizona Press, Tucson, pp. 113—120.

Mann, D.H., Hamilton, T.D., 1995. Late Pleistocene and holocene paleoenvironments of the north pacific coast. Quat. Sci. Rev. 14, 449—471.

Mann, D.H., Peteet, D.M., 1994. Extent and timing of the last glacial maximum in Southwestern Alaska. Quat. Res. 42, 136—148.

Margold, M., Stroeven, A.P., Clague, J.J., Heyman, J., 2014. Timing of terminal Pleistocene deglaciation at high elevations in southern and central British Columbia constrained by 10Be exposure dating. Quat. Sci. Rev. 99, 193—202.

Maschner, H.D.G., 2016. Archaeology of the eastern aleut region. In: Friesen, Max (Ed.), The Oxford Handbook of the Prehistoric Arctic. Oxford University Press, pp. 323—348.

Mathewes, R.W., Vogel, J.S., Southon, J.R., Nelson, D.E., 1985. Accelerator radiocarbon date confirms early deglaciation of the Queen Charlotte Islands. Can. J. Earth Sci. 22, 790—791.

McLaren, D., Rahemtulla, F., Fedje, D., et al., 2015. Prerogatives, Sea Level, and the Strength of Persistent Places: Archaeological Evidence for Long-term Occupation of the Central Coast of British Columbia. B. C. Stud, p. 155.

Meltzer, D.J., 1989. Why don't we know when the first people came to North America? Am. Antiq. 54, 471—490.

Meltzer, D.J., 2009. First Peoples in a New World: Colonizing Ice Age America. Univ of California Press.

Meyer, D., Liboiron, H., 1990. A Paleoindian drill from the Niska site in southern Saskatchewan. Plains Anthropol. 35, 299—302.

Miller, D.S., Holliday, V.T., Bright, J., 2013. Clovis across the continent. In: Waters, M.R., Goebel, T., Graf, K. (Eds.), Paleoamerican Odyssey. Center for the Study of the First Americans, Texas A&M Press, College Station, Texas, pp. 207—220.

Milner, A.M., Bailey, R.G., 1989. Salmonid colonization of new streams in Glacier Bay National Park, Alaska. Aquac. Res. 20, 179—192.

Misarti, N., Finney, B.P., Jordan, J.W., Maschner, H.D.G., Addison, J.A., Shapley, M.D., Krumhardt, A., Beget, J.E., 2012. Early retreat of the Alaska Peninsula glacier complex and the implications for coastal migrations of first Americans. Quat. Sci. Rev. 48, 1—6.

Mochanov, I., 2009. The Earliest Stages of Settlement by People of Northeast Asia. US Department of Interior, National Park Service, Shared [Beringian] Heritage Program.

Morrow, J.E., Fiedel, S.J., Johnson, D.L., Kornfeld, M., Rutledge, M., Wood, W.R., 2012. Pre-clovis in Texas? A critical assessment of the "Buttermilk Creek complex." J. Archaeol. Sci. 39, 3677—3682.

Morrow, J.E., Morrow, T.A., 1999. Geographic variation in fluted projectile points: a hemispheric perspective. Am. Antiq. 64, 215—230.

Moss, M.L., Cannon, A., 2011. The archaeology of north pacific fisheries: an introduction. In: Moss, M.L., Cannon, A. (Eds.), The Archaeology of Northern Pacific Fisheries. University of Alaska Press, pp. 1—16.

Moss, M.L., Erlandson, J.M., Byram, R.S., Hughes, R.E., 1996. The Irish Creek site: evidence for a mid-holocene microblade component on the northern northwest coast. Can. J. Archaeol./J. Can. d'Archéol. 20, 75—92.

Mulligan, C.J., Kitchen, A., Miyamoto, M.M., 2008. Updated three-stage model for the peopling of the Americas. PLoS One 3, e3199.

Munyikwa, K., Feathers, J.K., Rittenour, T.M., Shrimpton, H.K., 2011/6. Constraining the Late Wisconsinan retreat of the Laurentide ice sheet from western Canada using luminescence ages from postglacial aeolian dunes. Quat. Geochronol. 6, 407—422.

Munyikawa, K., Rittenour, T.M., Feathers, J.K., 2017. Temporal constraints for the Late Wisconsinan deglaciation of western Canada using eolian dune luminescence chronologies from Alberta. Palaeogeogr. Palaeoclimatol. Palaeoecol. http://dx.doi.org/10.1016/j.palaeo.2016.12.034.

Murray, C., Markager, S., Stedmon, C.A., Juul-Pedersen, T., Sejr, M.K., Bruhn, A., 2015. The influence of glacial melt water on bio-optical properties in two contrasting Greenlandic fjords. Estuar. Coast. Shelf Sci. 163 (Part B), 72—83.

Overstreet, D.F., Kolb, M.F., January 2003. Geoarchaeological contexts for Late Pleistocene archaeological sites with human-modified woolly mammoth remains in southeastern Wisconsin, U.S.A. Geoarchaeology 18 (1), 91—114. David F. Overstreet and Michael F. Kolb.

Pearson, G.A., 2004. Pan-American paleoindian dispersals and the origins of Fishtail projectile points as seen through the lithic raw-material reduction strategies and tool-manufacturing techniques at the guardiria site, turrialba valley, Costa Rica. In: Barton, C.M., Clark, G.A., Yesner, D.R., Pearson, G.A. (Eds.), The Settlement of the American Continents: a Multidisciplinary Approach to Human Biogeography. University of Arizona Press, pp. 85—102.

Pedersen, M.W., Ruter, A., Schweger, C., Friebe, H., Staff, R.A., Kjeldsen, K.K., Mendoza, M.L.Z., Beaudoin, A.B., Zutter, C., Larsen, N.K., Potter, B.A., Nielsen, R., Rainville, R.A., Orlando, L., Meltzer, D.J., Kjær, K.H., Willerslev, E., 2016.

Postglacial viability and colonization in North America's ice-free corridor. Nature 537, 45—49.

Perego, U.A., Achilli, A., Angerhofer, N., Accetturo, M., Pala, M., Olivieri, A., Hooshiar Kashani, B., Ritchie, K.H., Scozzari, R., Kong, Q.-P., Myres, N.M., Salas, A., Semino, O., Bandelt, H.-J., Woodward, S.R., Torroni, A., 2009. Distinctive Paleo-Indian migration routes from Beringia marked by two rare mtDNA haplogroups. Curr. Biol. 19, 1—8.

Perego, U.A., Angerhofer, N., Pala, M., Olivieri, A., Lancioni, H., Hooshiar Kashani, B., Carossa, V., Ekins, J.E., Gómez-Carballa, A., Huber, G., Zimmermann, B., Corach, D., Babudri, N., Panara, F., Myres, N.M., Parson, W., Semino, O., Salas, A., Woodward, S.R., Achilli, A., Torroni, A., 2010. The initial peopling of the Americas: a growing number of founding mitochondrial genomes from Beringia. Genome Res. 20, 1174—1179.

Peteet, D.M., Mann, D.H., 1994. Late-glacial vegetational, tephra, and climatic history of southwestern Kodiak Island, Alaska. Écoscience 1, 255—267.

Pitulko, V.V., Pavlova, E.Y., Basilyan, A.E., 2016. Mass accumulations of mammoth (mammoth 'graveyards') with indications of past human activity in the northern Yana-Indighirka lowland, Arctic Siberia. Quat. Int. 406, 202—217.

Potter, B.A., 2006. Site Location Model and Survey Strategy for Cultural Resources in the Alaska Railroad Northern Rail Extension Project Area. Prepared for ICF Consulting Services, LLC, by Northern Land Use Research, Inc. Fairbanks. NLUR Technical Report #278a.

Potter, B.A., 2007. Models of faunal processing and economy in Early Holocene interior Alaska. Environ. Archaeol. 12, 3—23.

Potter, B.A., 2008. Radiocarbon chronology of central Alaska: technological continuity and economic change. Radiocarbon 50, 181—204.

Potter, B.A., 2011. Late Pleistocene and early holocene assemblage variability in central Alaska. In: From the Yenisei to the Yukon: Interpreting Lithic Assemblage Variability in Late Pleistocene/Early Holocene Beringia, p. 215.

Potter, B.A., Bowers, P.M., Wooley, C.B., Gallison, J.D., Sheppard, W.L., Gelvin-Reymiller, C., Reuther, J.D., 2002. Results of the 2001 Phase I Cultural Resources Survey of the Proposed Alaska Gas Pipeline Project Area, Southern Route. Prepared for Alaska Gas Producers Pipeline Team by Northern Land Use Research, Inc., and Chumis Cultural Resource Services, Anchorage. NLUR Technical Report #147.

Potter, B.A., Bowers, P.M., Reuther, J.D., 2007. Holocene assemblage variability in the Tanana Basin: NLUR archaeological research, 1994—2004. Alaska J. Archaeol. 5.

Potter, B.A., Holmes, C.E., Yesner, D.R., 2013. Technology and economy among the earliest prehistoric foragers in interior Eastern Beringia. In: Paleoamerican Odyssey. Texas A&M Press, pp. 81—103.

Potter, B.A., Irish, J.D., Reuther, J.D., McKinney, H.J., 2014. New insights into Eastern Beringian mortuary behavior: a terminal Pleistocene double infant burial at Upward Sun River. Proc. Natl. Acad. Sci. U. S. A. 111, 17060—17065.

Powers, W.R., Guthrie, R.D., Hoffecker, J.F., 1983. Dry Creek: Archeology and Paleoecology of a Late Pleistocene Alaskan Hunting Camp. Report Submitted to the National Park Service. Contract.

Praetorius, S., Mix, A., Jensen, B., Froese, D., Milne, G., Wolhowe, M., Addison, J., Prahl, F., 2016. Interaction between climate, volcanism, and isostatic rebound in Southeast Alaska during the last deglaciation. Earth Planet. Sci. Lett. 452, 79—89.

Prasciunas, M.M., Surovell, T.A., Smallwood, A.M., Jennings, T.A., 2015. Reevaluating the duration of Clovis: the problem of non-representative radiocarbon dates. In: Clovis: on the edge of a new understanding, pp. 21—35.

Raghavan, M., Steinrücken, M., Harris, K., Schiffels, S., Rasmussen, S., DeGiorgio, M., Albrechtsen, A., Valdiosera, C., Ávila-Arcos, M.C., Malaspinas, A.-S., Eriksson, A., Moltke, I., Metspalu, M., Homburger, J.R., Wall, J., Cornejo, O.E., Moreno-Mayar, J.V., Korneliussen, T.S., Pierre, T., Rasmussen, M., Campos, P.F., Damgaard, P. de B., Allentoft, M.E., Lindo, J., Metspalu, E., Rodríguez-Varela, R., Mansilla, J., Henrickson, C., Seguin-Orlando, A., Malmström, H., Stafford Jr., T., Shringarpure, S.S., Moreno-Estrada, A., Karmin, M., Tambets, K., Bergström, A., Xue, Y., Warmuth, V., Friend, A.D., Singarayer, J., Valdes, P., Balloux, F., Leboreiro, I., Vera, J.L., Rangel-Villalobos, H., Pettener, D., Luiselli, D., Davis, L.G., Heyer, E., Zollikofer, C.P.E., Ponce de León, M.S., Smith, C.I., Grimes, V., Pike, K.-A., Deal, M., Fuller, B.T., Arriaza, B., Standen, V., Luz, M.F., Ricaut, F., Guidon, N., Osipova, L., Voevoda, M.I., Posukh, O.L., Balanovsky, O., Lavryashina, M., Bogunov, Y., Khusnutdinova, E., Gubina, M., Balanovska, E., Fedorova, S., Litvinov, S., Malyarchuk, B., Derenko, M., Mosher, M.J., Archer, D., Cybulski, J., Petzelt, B., Mitchell, J., Worl, R., Norman, P.J., Parham, P., Kemp, B.M., Kivisild, T., Tyler-Smith, C., Sandhu, M.S., Crawford, M., Villems, R., Smith, D.G., Waters, M.R., Goebel, T., Johnson, J.R., Malhi, R.S., Jakobsson, M., Meltzer, D.J., Manica, A., Durbin, R., Bustamante, C.D., Song, Y.S., Nielsen, R., Willerslev, E., 2015. Genomic evidence for the Pleistocene and recent population history of Native Americans. Science 349, aab3884.

Ramsey, C.L., Griffiths, P.A., Fedje, D.W., Wigen, R.J., Mackie, Q., 2004. Preliminary investigation of a late wisconsinan fauna from K1 cave, Queen Charlotte Islands (Haida Gwaii), Canada. Quat. Res. 62, 105—109.

Rasmussen, M., Anzick, S.L., Waters, M.R., Skoglund, P., DeGiorgio, M., Stafford Jr., T.W., Rasmussen, S., Moltke, I., Albrechtsen, A., Doyle, S.M., Poznik, G.D., Gudmundsdottir, V., Yadav, R., Malaspinas, A.-S., White 5th, S.S., Allentoft, M.E., Cornejo, O.E., Tambets, K., Eriksson, A., Heintzman, P.D., Karmin, M., Korneliussen, T.S., Meltzer, D.J., Pierre, T.L., Stenderup, J., Saag, L., Warmuth, V.M., Lopes, M.C., Malhi, R.S., Brunak, S., Sicheritz-Ponten, T., Barnes, I., Collins, M., Orlando, L., Balloux, F., Manica, A., Gupta, R., Metspalu, M., Bustamante, C.D., Jakobsson, M., Nielsen, R., Willerslev, E., 2014. The genome of a Late Pleistocene human from a Clovis burial site in western Montana. Nature 506, 225—229.

Rech, J.A., Nekola, J.C., Pigati, J.S., 2012. Radiocarbon ages of terrestrial gastropods extend duration of ice-free conditions at the Two Creeks forest bed, Wisconsin, USA. Quat. Res. 77 (2), 289—292.

Reger, R.D., Pinney, D.S., 1996. Late Wisconsin glaciation of the Cook Inlet region with emphasis on Kenai lowland and implications for early peopling. In: Yaw, Nancy, Davis, William E. (Eds.), Adventures through Time: Readings in the Anthropology of Cook Inlet, Alaska: Proceedings of a Symposium. The Cook Inlet Historical Society, Anchorage.

Reich, D., Patterson, N., Campbell, D., Tandon, A., Mazieres, S., Ray, N., Parra, M.V., Rojas, W., Duque, C., Mesa, N., García, L.F., Triana, O., Blair, S., Maestre, A., Dib, J.C., Bravi, C.M., Bailliet, G., Corach, D., Hünemeier, T., Bortolini, M.C., Salzano, F.M., Petzl-Erler, M.L., Acuña-Alonzo, V., Aguilar-Salinas, C., Canizales-Quinteros, S., Tusié-Luna, T., Riba, L., Rodríguez-Cruz, M., Lopez-Alarcón, M., Coral-Vazquez, R., Canto-Cetina, T., Silva-Zolezzi, I., Fernandez-Lopez, J.C., Contreras, A.V., Jimenez-Sanchez, G., Gómez-Vázquez, M.J., Molina, J., Carracedo, A., Salas, A., Gallo, C., Poletti, G., Witonsky, D.B., Alkorta-Aranburu, G., Sukernik, R.I., Osipova, L., Fedorova, S.A., Vasquez, R., Villena, M., Moreau, C., Barrantes, R., Pauls, D., Excoffier, L., Bedoya, G., Rothhammer, F., Dugoujon, J.-M., Larrouy, G., Klitz, W., Labuda, D., Kidd, J., Kidd, K., Di Rienzo, A., Freimer, N.B., Price, A.L., Ruiz-Linares, A., 2012. Reconstructing native american population history. Nature 488, 370—374.

Reimer, P.J., Bard, E., Bayliss, A., Beck, J.W., Blackwell, P.G., Bronk Ramsey, C., Buck, C.E., Cheng, H., Edwards, R.L., Friedrich, M., Others, 2013. IntCal13 and Marine13 Radiocarbon Age Calibration Curves 0-50,000 Years Cal BP.

Reuther, J.D., Rogers, J.S., Gelvin-Reymiller, C., Higgs, A., Woolley, C., Baxter-McIntosh, J., Bowman, R.C., Hall, P.T., 2013. Results of the 2013 Phase I and II Cultural Resources Survey of the Proposed Donlin Gold Natural Gas Pipeline Study. Report prepared for the Alaska Office of History and Archaeology and the Bureau of Land Management, Anchorage, by Northern Land Use Research, Inc., Fairbanks, and Chumis Cultural Resources Services, Anchorage. NLUR Technical Report. On File at the Alaska Office of History and Archaeology.

Reuther, J.D., Slobodina, N.S., Rasic, J.T., Cook, J.P., Speakman, R.J., 2011. Gaining momentum: late Pleistocene and early holocene archaeological obsidian source studies in interior and northeastern Beringia. In: Goebel, T.E., Buvit, I. (Eds.), From the Yenisei to the Yukon: Interpreting Lithic Assemblage Variability in Late Pleistocene/Early Holocene Beringia. Texas A&M University Press, pp. 270—286.

Sancetta, C., Heusser, L., Labeyrie, L., Naidu, A.S., Robinson, S.W., 1985. Wisconsin-Holocene paleoenvironment of the Bering Sea: evidence from diatoms, pollens, oxygen isotopes, and clay minerals. Mar. Geol. 62, 55—68.

Sanchez, G., Holliday, V.T., Gaines, E.P., Arroyo-Cabrales, J., Martínez-Tagüeña, N., Kowler, A., Lange, T., Hodgins, G.W.L., Mentzer, S.M., Sanchez-Morales, I., 2014. Human (Clovis)—gomphothere (Cuvieronius sp.) association 13,390 calibrated yBP in Sonora, Mexico. Proc. Natl. Acad. Sci. 111, 10972—10977.

Sarnthein, M., Kiefer, T., Grootes, P.M., Elderfield, H., Erlenkeuser, H., 2006. Warmings in the far northwestern Pacific promoted pre-Clovis immigration to America during Heinrich event 1. Geology 34, 141—144.

Sawyer, Y.E., Cook, J.A., 2016. Phylogeographic structure in long-tailed voles (Rodentia: arvicolinae) belies the complex Pleistocene history of isolation, divergence, and recolonization of Northwest North America's fauna. Ecol. Evol. 18.

Schwarcz, H.P., Chisholm, B.S., Burchell, M., 2014. Isotopic studies of the diet of the people of the coast of British Columbia. Am. J. Phys. Anthropol. 155, 460—468.

Shafer, A.B.A., Cullingham, C.I., Côté, S.D., Coltman, D.W., 2010. Of glaciers and refugia: a decade of study sheds new light on the phylogeography of northwestern North America. Mol. Ecol. 19, 4589—4621.

Shapiro, B., Drummond, A.J., Rambaut, A., Wilson, M.C., Matheus, P.E., Sher, A.V., Pybus, O.G., Gilbert, M.T.P., Barnes, I., Binladen, J., Willerslev, E., 2004. Rise and fall of the Beringian steppe bison. Science 306 (5701), 1561—1565.

Sharp, R.P., 1958. The latest major advance of Malaspina Glacier, Alaska. Geogr. Rev. 48 (1), 16—26.

Shugar, D.H., Walker, I.J., Lian, O.B., Eamer, J.B.R., Neudorf, C., McLaren, D., Fedje, D., 2014. Post-glacial sea-level change along the Pacific coast of North America. Quat. Sci. Rev. 97, 170—192.

Skoglund, P., Mallick, S., Bortolini, M.C., Chennagiri, N., Hünemeier, T., Petzl-Erler, M.L., Salzano, F.M., Patterson, N., Reich, D., 2015. Genetic evidence for two founding populations of the Americas. Nature 525 (7567), 104—108.

Skoglund, P., Reich, D., 2016. A genomic view of the peopling of the Americas. Curr. Opin. Genet. Dev. 41, 27—35.

Smith, H.L., Smallwood, A.M., DeWitt, T.J., 2014. Defining the normative range of Clovis fluted point shape using geographic models of geometric morphometric variation. In: Clovis: on the Edge of a New Understanding. Texas A&M Press, College Station.

Speakman, R.J., Holmes, C.E., Glascock, M.D., 2007. Source determination of obsidian artifacts from Swan Point (XBD-156), Alaska. Curr. Res. Pleistocene 24, 143—145.

Speakman, Robert J., McGimsey, Robert G., Davis, Ricahrd, Yarborough, Michael, Rasic, Jeff, 2012. Aleutian Island and Alaska Peninsula Obsidian.

Spear, R.W., Cwynar, L.C., 1997. Late Quaternary vegetation history of white pass, Northern British Columbia, Canada. Arct. Alp. Res. 29, 45—52.

Spurkland, T., Iken, K., 2011. Kelp bed dynamics in estuarine environments in Subarctic Alaska. J. Coast. Res. 133—143.

Steffian, A.F., Pontti-Eufemio, E., Saltonstall, P.G., 2002. Early Sites and Microblade Technologies from the Kodiak Archipelago. In: Anthropological Papers of the University of Alaska New Series 2, pp. 1—38.

Straus, L.G., Meltzer, D.J., Goebel, T., 2005. Ice age Atlantis? Exploring the Solutrean-Clovis "connection." World Archaeol. 37, 507–532.

Stroeven, A.P., Fabel, D., Codilean, A.T., Kleman, J., Clague, J.J., Miguens-Rodriguez, M., Xu, S., 2010. Investigating the glacial history of the northern sector of the Cordilleran Ice Sheet with cosmogenic 10Be concentrations in quartz. Quat. Sci. Rev. 29, 3630–3643.

Stroeven, A.P., Fabel, D., Margold, M., Clague, J.J., Xu, S., 2014. Investigating absolute chronologies of glacial advances in the NW sector of the Cordilleran Ice Sheet with terrestrial in situ cosmogenic nuclides. Quat. Sci. Rev. 92, 429–443.

Surovell, T.A., 2003. The Behavioral Ecology of Folsom Lithic Technology (Ph.D). University of Arizona.

Syverson, K.M., Colgan, P.M., 2011. The Quaternary of Wisconsin: an updated review of stratigraphy, glacial history and landforms. In: Ehlers, Jürgen, Gibbard, Philip L, Hughes, Philip D. (Eds.), Quaternary Glaciations - Extent and Chronology, Developments in Quaternary Science, vol. 15. Elsevier, pp. 537–552.

Tamm, E., Kivisild, T., Reidla, M., Metspalu, M., Smith, D.G., Mulligan, C.J., Bravi, C.M., Rickards, O., Martinez-Labarga, C., Khusnutdinova, E.K., Fedorova, S.A., Golubenko, M.V., Stepanov, V.A., Gubina, M.A., Zhadanov, S.I., Ossipova, L.P., Damba, L., Voevoda, M.I., Dipierri, J.E., Villems, R., Malhi, R.S., 2007. Beringian standstill and spread of Native American founders. PLoS One 2, e829.

Wang, S., Lewis Jr., C.M., Jakobsson, M., Ramachandran, S., Ray, N., Bedoya, G., Rojas, W., Parra, M.V., Molina, J.A., Gallo, C., Mazzotti, G., 2007. Genetic variation and population structure in Native Americans. PLoS Genet. 3 (11), e185.

Waters, M.R., Stafford, T.W., 2014. Redating the Mill Iron site, Montana: a reexamination of the Goshen complex chronology. Am. Antiq. 79, 541–548.

Waters, M.R., Stafford Jr., T.W., McDonald, H.G., Gustafson, C., Rasmussen, M., Cappellini, E., Olsen, J.V., Szklarczyk, D., Jensen, L.J., Gilbert, M.T.P., Willerslev, E., 2011. Pre-Clovis mastodon hunting 13,800 years ago at the Manis site, Washington. Science 334, 351–353.

Waters, M.R., Stafford, T.W., Graf, K., Ketron, C.V., 2013. The first Americans: a review of the evidence for the late-Pleistocene peopling of the Americas. In: Paleoamerican.

Waters, M.R., Amorosi, T., Stafford Jr., Thomas, W., 2015. Redating Fell's cave, Chile and the chronological placement of the Fishtail projectile point. Am. Antiq. 80, 376–386.

Waters, M.R., Stafford Jr., T.W., 2007. Redefining the age of Clovis: implications for the peopling of the Americas. Science 315, 1122–1126.

West, F.H., 1996. Beringia and New World origins II. The archaeological evidence. In: West, F.H. (Ed.), American Beginnings: The Prehistory and Palaeoecology of Beringia. University of Chicago Press, Chicago, pp. 537–559.

White, J.M., Mathewes, R.W., Mathews, W.H., 1985. Late Pleistocene chronology and environment of the "ice-free corridor" of northwestern Alberta. Quat. Res. 24, 173–186.

Wiedmer, M., Montgomery, D.R., Gillespie, A.R., Greenberg, H., 2010. Late Quaternary megafloods from Glacial Lake atna, Southcentral Alaska, USA. Quat. Res. 73, 413–424.

Wilson, M.C., Kenady, S.M., Schalk, R.F., 2009. Late Pleistocene Bison antiquus from Orcas Island, Washington, and the biogeographic importance of an early post-glacial land mammal dispersal corridor from the mainland to Vancouver Island. Quat. Res. 71, 49–61.

Wolfe, S.A., Huntley, D.J., Ollerhead, J., 2004. Relict late Wisconsinan dune fields of the northern Great Plains, Canada. Géogr. Phys. Quat. 58, 323–336.

Wolfe, S.A., Paulen, R.C., Smith, I.R., Lamothe, M., 2007. Age and paleoenvironmental significance of Late Wisconsinan dune fields in the Mount Watt and Fontas River map areas, northern Alberta and British Columbia. Geol. Surv. Can. Curr. Res. 2007 (B4), 10.

Wygal, B.T., Goebel, T., 2012. Early prehistoric archaeology of the Middle Susitna valley, Alaska. Arct. Anthropol. 49, 45–67.

Yamamoto, S., Maekawa, K., Morita, K., Crane, P.A., Oleinik, A.G., 2014. Phylogeography of the salmonid fish, Dolly Varden Salvelinus malma: multiple glacial refugia in the North Pacific Rim. Zool. Sci. 31, 660–670.

Yesner, D.R., Ayres, W.S., Carlson, D.L., Davis, R.S., Dewar, R., González Morales, Manuel R., Hassan, F.A., Hayden, B., Lischka, J.J., Sheets, P.D., Osborn, A., Pokotylo, D.L., Rogers, T., Spanier, E., Turner, B.L., Wreschner, E.E., 1980. Maritime hunter-gatherers: ecology and prehistory [and comments and reply]. Curr. Anthropol. 21, 727–750.

Yesner, D.R., 1998. Origins and development of maritime adaptations in the northwest pacific region of North America: a zooarchaeological perspective. Arct. Anthropol. 35, 204–222.

Yesner, D.R., 2001. Human dispersal into interior Alaska: antecedent conditions, mode of colonization, and adaptations. Quat. Sci. Rev. 20, 315–327.

Yi, S., Clark, G., Aigner, J.S., Bhaskar, S., Dolitsky, A.B., 1985. The" Dyuktai Culture" and New World Origins. Current.

Zazula, G.D., MacKay, G., Andrews, T.D., Shapiro, B., Letts, B., Brock, F., 2009. A late Pleistocene steppe bison (Bison priscus) partial carcass from Tsiigehtchic, Northwest Territories, Canada. Quat. Sci. Rev. 28, 2734–2742.

Zegura, S.L., Karafet, T.M., Zhivotovsky, L.A., Hammer, M.F., 2004. High-resolution SNPs and microsatellite haplotypes point to a single, recent entry of Native American Y chromosomes into the Americas. Mol. Biol. Evol. 21, 164–175.